PRINTED ON THIN PAPER FOR FOREIGN CIRCULATION

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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD STREET, STRAND, LONDON, W.C. 2

VOL. CIX.—No. 2822.] [*Registered at the General Post Office as a Newspaper.*] *LONDON: FRIDAY, JANUARY 30, 1920.* [DOUBLE NUMBER WITH INDEX. PRICE...9d. BY FOREIGN POST ... 9d. 5d.

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See Advertisement page 99, Jan. 23.

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PRESSURE, AIR, STEAM.
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4078

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See Advertisement page 86. 8187

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8181
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JOHN M. HENDERSON & CO., ABERDEEN.

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Destroyers, Torpedo Boats, Yachts and Fast Boats, Submarine and Submersible Boats.
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Engines and Dynamos could be sold separately.
Also TWO 500 Kw. Parsons TURBINES, 250 Volts, D.C., complete with Spare Armature and Condenser.
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FEED WATER HEATERS, CALORIFIERS, EVAPORATORS, CONDENSERS, AIR HEATERS, STEAM AND GAS KETTLES. } Row's PATENTS
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High-class GUNMETAL STEAM FITTINGS
WATER SOFTENING and FILTERING. 6132

Yarrow Patent
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7766
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YARROW & CO., LTD., SCOTSTOUN, GLASGOW.

Matthew Paul & Co., Ltd.
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See Full Page Advt., page 78, Jan. 9.

Forgings.
Walter Somers & Co., Ltd.,
HALESOWEN. 7116

Head, Wrightson & Co.,
LIMITED.
See Advertisement page 28. 9403

Taylor & Challen Presses.
8195
TAYLOR & CHALLEN, LD., Engineers, BIRMINGHAM
See Full Page Advertisement, Jan. 9.

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MANUFACTURERS OF
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OF ALL DESCRIPTIONS.
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Agents: MARINE WORKS, LTD., FRIARS HOUSE, 39-41, NEW BROAD ST., LONDON, E.C. 2.
See half-page Advert. last week and next week. 7198

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MOTHERWELL, SCOTLAND. 7846
See half-page Advertisement page 95, Jan. 23.

The Manchester Steam Users' ASSOCIATION

For the prevention of Steam Boiler Explosions and for the Attainment of Economy in the Application of Steam. 9, Mount Street, Manchester.
Chief Engineer: C. B. STROMEYER, M.I.C.E.
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(Registered under the Trade Union Act.)

An Association specially formed to look after the interests of Foremen on their Supervisory Capacity. C 509

All communications to— H. W. RHID, General Secretary. Head Offices— 91, High Holborn London, W.C.1.

NOTICE.

T. A. SAVERY & COMPANY, LIMITED, Engineers, Newcomen Works, Birmingham.

Notice is Hereby Given that

Mr. H. T. Backhouse, of 15, Palace Court, London, W. (lately residing at the Midland Hotel, Birmingham) is not now connected in any way whatever with this Company, neither is he authorised to act for or represent it in any capacity whatsoever.

By Order of the Board,
A. M. LLOYD,
Secretary.
D 166

Inst. C.E. Exams.—Over 300

successes by Correspondence Coaching. Several prizes. Sec. "O" now prepared. (Designs, Specifications and Quantities). A few vacancies open.—Address, 7434 Offices of Engineering.

Correspondence Courses for

B.Sc., Inst.C.E., I.Mech.E., All Technical Exams. Special Courses and Single Subjects. Fees moderate.—For full particulars apply to Mr. TREVOR W. PHILLIPS, B.Sc. Honours (Eng.), A.M.I.C.E., &c., 5-10, Trafford Chambers, 58, South John Street, Liverpool 8071

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TENDERS.

For Sale by Tender, Pair of

DOCK GATES in good condition, suitable for 50 ft. entrance, and containing 2830 cubic feet of Sound Greenheart timber of large scantling.

For further particulars apply to J. B. HAMILTON, Harbour Office, Workington, Cumberland. D 132

COUNTY BOROUGH OF ST. HELENS.

Tenders are Invited for the

SUPPLY of—

One STEAM-DRIVEN TURBINE FEED PUMP, capable of delivering 125,000 lbs. of water per hour, under conditions set out in Specification.

Specifications may be obtained from the Borough Electrical Engineer.

Sealed Tenders should be sent in by 7th February, 1920, addressed to the Chairman of the Electricity Committee, Electricity Works, St. Helens.

B. T. HAWKINS,
Borough Electrical Engineer.
D 141

CITY OF MELBOURNE, AUSTRALIA.

SUPPLY OF—
(a) TWO 2000 KW. ROTARY CONVERTERS.
(b) H.T. SWITCHGEAR, 6600 VOLTS.
(c) D.C. SWITCHGEAR, 600 VOLTS.

Tenders are Invited for the

SUPPLY and DELIVERY in MELBOURNE of TWO 2000 KW. ROTARY CONVERTERS and a QUANTITY of SWITCHGEAR.

Tender form with specifications, etc., can be obtained on application to McILWRAITH, McEACHARN and Co. Proprietary, Ltd., Billiter Square Buildings, London, E.C. 3. Such application must be accompanied by a deposit of one guinea, which will be returned on advice from Melbourne that a bona fide tender has been received.

Extra copies of the specification, etc., can be obtained on payment of 5s. per copy, which sum will not be returnable.

The Tender form must be filled up and returned intact, together with the specification, conditions of contract, etc., and all particulars, sealed and endorsed "Electrical Equipment," and addressed to The Town Clerk, Town Hall, Melbourne, Australia, and must be received by him before 2 p.m. on Monday, 12th April, 1920.

Each Tenderer must send in with his Tender, either in cash or by bank draft, a deposit equal in amount to 2½ per cent. upon the amount of his tender, as a guarantee of good faith, and in the event of his Tender being accepted by the Council, he must forthwith increase his deposit to any amount equal to 5 per cent. upon the amount of his Tender, as a security for the due performance of his contract. This deposit may, if desired, be handed to Messrs. McILWRAITH, McEACHARN & Co. Proprietary, Ltd., in which case their receipt for same must accompany the Tender.

The Council does not bind itself to accept the lowest or any Tender, nor will it be responsible, nor pay for, expenses or losses which may be incurred by any Tenderer in the preparation of his Tender.

McILWRAITH, McEACHARN & CO. PROPRIETARY, Ltd.,
Billiter Square Buildings,
London, E.C. 3.
Agents for the Melbourne City Council. D 131

THE COMMISSIONERS OF HIS MAJESTY'S WORKS, &c., are prepared to receive

Tenders, before Eleven

a.m. on Monday, 9th February, 1920, addressed to the SECRETARY, H.M. Office of Works, &c., Storey's Gate, Westminster, London, S.W. 1, for the SUPPLY of CAST IRON PIPES and ACCESSORIES (during a period of six months from date of acceptance of Tender).

Forms of Tender, &c., may be obtained on application to the CONTROLLER OF SUPPLIES, H.M. Office of Works, etc., King Charles Street, Westminster, London, S.W. 1. D 173

KIRKCALDY, FIFE.

Tenders are Invited for the

Desirable FREEHOLD PREMISES, WORKSHOPS and OFFICES of THE STEEL PIPE COMPANY, LIMITED, Dunnikier Road, Kirkcaldy.

Together with Machinery and Plant, Fixtures and Fittings, Tools, Utensils, Stock, etc., belonging to above Company, suitable for all structural steel work.

TO BE SOLD BY PRIVATE TREATY.

May be viewed by appointment.

Apply, THOS. SMITH, 121, Dunnikier Road, Kirkcaldy. D 51

COUNTY BOROUGH OF SALFORD.

The Electricity Department have

For Sale One 1000 Kilowatt

DIRECT CURRENT TURBO GENERATOR, Willans-Parsons type, coupled to Brown-Boveri Generator, voltage 460-485, rated output 1000 kilowatts, with 160 lb. steam pressure, the set is in regular commission and can be seen in operation by appointment.

Full particulars from the BOROUGH ELECTRICAL ENGINEER, Electricity Works, Frederick Road, Salford.

TENDERS are INVITED not later than Twelve Noon, Monday, February 14th, 1920.

L. C. EVANS,
Town Clerk. D 219

LONDON COUNTY COUNCIL.

The Council invites

Tenders for New Machinery

for their twin-screw sludge vessel "Bazalgette" (total I.HP. 700) and REPAIRS to VESSEL.

Persons desiring to Tender may obtain specifications and further information from the Chief Engineer, County Hall, Spring Gardens, S.W. 1, upon payment to the Cashier of £3. This amount will be returnable only if the tenderer shall have made a *bona-fide* tender and shall not have withdrawn the same.

Particulars may be obtained and the specification inspected at the County Hall before the fee is paid.

No Tender received at the County Hall after 4 p.m. on Monday, 8th March, 1920, will be considered.

JAMES BIRD,
Clerk of the London County Council. D 218

INDIA OFFICE, WHITEHALL.

THE SECRETARY OF STATE FOR INDIA IN COUNCIL is prepared to receive

Tenders from such per-

sons as may be willing to supply AXLEBOXES FOR ROLLING STOCK.

The Conditions of Contract may be obtained on application to the Director-General of Stores, India Office, Whitehall, S.W., and Tenders are to be delivered at that Office by *Two o'clock* p.m., on Tuesday, the 17th February, 1920, after which time no Tender will be received.

J. STEVENS,
Acting Director-General of Stores.
23rd January, 1920. D 221

COUNTY BOROUGH OF WALLASEY.

GAS AND WATER DEPARTMENT.

THE WALLASEY CORPORATION are prepared to receive

Tenders for the following

MATERIAL required for their Railway Siding Renewals at the Gas and Water Works.

The price is to include delivery of:—

About 30 TONS F.B. RAILS OF STANDARD SECTION, 75 lbs. per Yard.

Further particulars and Specification may be had upon application to the Gas and Water Engineer, Mr. J. H. CROWTHER, at his Office, Limeklin Lane, Wallasey, Cheshire.

Sealed Tenders, addressed to the undersigned, and endorsed "Tender for Railway Siding Materials, Gas Works," to be delivered per post at my Office as below, not later than the morning of TUESDAY, 17TH FEBRUARY, 1920. Tenders arriving after that date will not be considered.

The Council do not bind themselves to accept the lowest or any tender.

Dated this 23rd day of January, 1920.

H. W. COOK,
Town Clerk.

Town Hall,
Wallasey. D 158

LONDON COUNTY COUNCIL.

The Council invites

Tenders, for Laying and

FIXING of about 1½ miles of CAST-IRON SOCKET PIPES, 24 in. diameter, and works connected therewith, partly in the Borough of East Ham, and partly in the Metropolitan Borough of Woolwich.

The Specifications, Bills of Quantities, Form of Tender, Drawings, &c. may be obtained on application to THE CHIEF ENGINEER, at the County Hall, Spring Gardens, S.W., upon payment to the Cashier of the Council the sum of £5. This amount will be returnable only if the Tenderer shall have sent in a *bona fide* Tender and shall not have withdrawn the same.

Full particulars may be obtained, and the drawings, specification and other contract documents may be inspected, at the County Hall, before the payment of the fee.

Tenders must be upon the official forms, and no tender received at the County Hall after Four p.m. on Monday, 23rd February, 1920, will be considered.

The Council does not bind itself to accept the lowest or any tender.

JAMES BIRD, D 220
Clerk of the London County Council.

INTERNATIONAL COMPETITION.

Aalborg Town Council's

COMMITTEE of King Chr. IX Pontoon Bridge HEREBY INVITE DESIGNS for a New BRIDGE CONNECTION ACROSS THE LIMFJORD, BETWEEN AALBORG AND NORRESUNDBY (DENMARK).

Three Prizes are offered, viz.:—

1st Prize	... ...	Kroner 10,000.00
2nd ,,	... ...	,, 6,000.00
3rd ,,	... ...	,, 4,000.00

The Committee furthermore reserve the right to purchase some plans which have received no prize, at a sum of Kroner 2000.00 each.

The plans are to be submitted before September 30th, 1920.

Program with descriptions, maps, etc., will be furnished in the Danish, English, German, or French language, on application to the HARBOUR ENGINEER'S OFFICE, Nyhavnsgade 12, Aalborg, Denmark, against a deposit of Kroner 50.00, which amount will be refunded to those who submit plans in due time, or return the documents furnished in undamaged condition before the expiration of the time stipulated for the competition.

THE COMMITTEE OF KING CHR. IX PONTOON BRIDGE.

Aalborg,
January 1st, 1920. C 903

MANCHESTER CORPORATION WATERWORKS.

The Waterworks Committee invite

Tenders for the Supply and

ERECTION at Thirlmere of the following PLANT:—

Contract No. 1.—Water Turbine, Dynamo, Switchboard, &c.
Contract No. 2.—Storage Battery, Reversible Booster, Motor Generator, Switchboard, &c.
Contract No. 3.—D.C. Motors, Starting Panels, &c.
Contract No. 4.—L.T. Paper Insulated Lead Covered Cables.

Copies of the Specifications and Forms of Tender may be obtained from the Secretary, Water Department, Town Hall, Manchester, on receipt of a deposit of two guineas for each copy. The deposit in respect of each Contract will be returned on receipt of a bona fide Tender.

All enquiries respecting the work are to be addressed to the Waterworks Engineer.

Tenders must be delivered not later than 21st February next.

By order,
THOMAS HUDSON,
Town Clerk.

Town Hall, Manchester.
21st January, 1920. D 279

PORT OF BRISTOL.

FERRO-CONCRETE RECONSTRUCTION OF THE UPPER PART OF THE LOWER PONTOON, HOTWELLS LANDING STAGE, BRISTOL.

The Docks Committee Invite

Tenders for the Ferro-Concrete

RECONSTRUCTION of the Upper Part of the Lower Pontoon, Hotwells Landing Stage, Bristol. The reconstructed decking will be approximately 60 ft. by 28 ft. by 4 ft. 6 in.

On and after Monday, the 2nd February, 1920, a copy of the Form of Tender, General Conditions, Specification, Schedule of Prices, and a copy of the Contract Drawings can be obtained from the undersigned on production of a receipt shewing that a deposit of £2 has been paid to the General Manager and Secretary of the Docks Committee, 19, Queen Square, Bristol, to whom all cheques must be made payable. The deposit of £2 will be returned hereafter to all bona fide tenderers.

Tenders must be enclosed in a sealed envelope, endorsed "Tender for Reconstruction of Pontoon Decking, Hotwells," and addressed to the General Manager and Secretary of the Bristol Docks Committee, Dock Office, 19, Queen Square, Bristol, and must be delivered to him accompanied by the prescribed documents and drawings on or before 10 a.m. on Monday, the 16th day of February, 1920.

THOMAS A. PEACE,
Engineer's Office, Engineer.
Avonmouth Docks.
28th January, 1920. D 292

METROPOLITAN WATER BOARD.

TENDERS FOR THE SUPPLY AND ERECTION OF A BOREHOLE PUMP AT SUNDRIDGE, KENT.

The Metropolitan Water Board Invite

Tenders for the Supply and

ERECTION of a BOREHOLE PUMP at their Pumping Station at Sundridge, Kent.

Forms of Tender, Conditions of Contract, Specification and Drawing may be obtained at the Offices of the Board, Chief Engineer's Department, South Place, Finsbury Pavement, E.C. 2, on and after Wednesday, 4th February, 1920, on production of an official receipt for the sum of One Guinea, which sum must be deposited with the Board's Accountant at South Place, Finsbury Pavement, and will be returned on receipt of a bona fide tender with all incidental papers.

Such payments and applications must be made between the hours of Ten a.m. and Four p.m. (Saturdays Ten a.m. and Twelve noon).

Tenders enclosed in sealed envelopes addressed to "The Clerk of the Board, Metropolitan Water Board, South Place, Finsbury Pavement, E.C. 2," and endorsed "Tender for Borehole Pump, Sundridge," must be delivered at the Offices of the Board not later than Ten a.m. on Friday, 27th February, 1920.

A. B. PILLING,
Clerk of the Board.

2, South Place,
Finsbury Pavement, E.C. 2.
24th January, 1920. D 309

APPOINTMENTS OPEN.

A Large Firm of Engineers

in the Midlands have an OPENING for a YOUTH of good education as premium pupil, the course to include both works and drawing office.—Address, 4350, Offices of Engineering.

Demonstrators (two) Required.

One for fitting and one for turning. Staff appointments and permanent jobs to suitable men. —State full experience and age to JOHN I. THORNYCROFT & CO., Ltd., Basingstoke. D 248

BLACKBURN MUNICIPAL TECHNICAL SCHOOL.

An Assistant Lecturer in

Mechanical and Electrical Engineering REQUIRED immediately. Salary £325. For further particulars apply to the Principal.

A. H. WHIPPLE, M.A., B.Sc.,
Director of Education.
D 244

BIRMINGHAM MUNICIPAL TECHNICAL SCHOOL.

Applications are Invited for

LECTURESHIP in MECHANICAL ENGINEERING. The appointment is on a salary scale rising to £380. The commencing salary offered will be dependent upon the experience of the applicant. In addition to the salary there is at the present time a war allowance of £74 to £78 per annum.—Full particulars may be obtained on application to the SECRETARY, Municipal Technical School, Suffolk Street, Birmingham. D 137

WIGAN AND DISTRICT MINING AND TECHNICAL COLLEGE.

Wanted, Lecturer in Engi-

NEERING. Salary according to scale. Maximum £450 with possibility of subsequent increase to £500.

Initial salary up to £300 according to qualifications and experience.

Further particulars may be had from the PRINCIPAL, to whom applications should be sent as early as possible D 215

UNIVERSITY OF BIRMINGHAM.

CIVIL ENGINEERING DEPARTMENT.
Professor F. C. Lea, D.Sc., M.Inst.C.E.

Applications are Invited for

the POST of LECTURER in the Civil Engineering Department to succeed Mr. W. N. Thomas, M.Sc., A.M.Inst.C.E., who has been appointed Assistant to the Professor of Engineering in the University of Oxford.

Stipend £350 per annum.

Applications, with testimonials and references, should be forwarded to the undersigned not later than Monday, the 23rd of February, 1920.

Further particulars may be obtained from
GEO. H. MORLEY, D 122
Secretary.

MINISTRY OF PENSIONS.

CONVALESCENT CENTRES.

Instructors Required as

follows:—

CHIEF INSTRUCTORS £350–£450.
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THE AEROPLANE OF CONSISTENT STRENGTH.

By A. J. SUTTON PIPPARD, M.Sc., A.M.I.C.E.

1. AT the present time it is customary to specify the structural strength of an aeroplane by means of at least three arbitrary factors. These are: (*a*) The load factor of the front truss assuming the centre of pressure on the wings to be in its most forward position; (*b*) the load factor of the rear truss, assuming the centre of pressure on the wings to be at some arbitrary position corresponding approximately to top speed horizontal flight; and (*c*) the factor of safety of the structure when diving at terminal velocity.

The values to be assigned to these factors in any particular case have been arrived at as the result of experience; and the best that can be said for the system is that after fairly exhaustive trial it has proved satisfactory.

With the existing method, there is no connection between the various factors specified, so that it is not possible directly to compare the structural strength of different aeroplanes. Further, and this is a more serious point, the system does not conduce to that uniformity of strength which is the essential in all good structural design.

It should be possible, however, to formulate a simpler basis in order to obtain more consistent structural strength, and in this paper the author presents one solution of the problem.

Many of the conditions of flight to which an aeroplane may be subjected are such that a complete solution of the problem of the loads involved is only amenable to complicated mathematical analysis. The results of such analysis, while of extreme interest from the scientific point of view, are often given in such a form as to be of comparatively little immediate value to the designer. Fortunately, however, in most cases by making various assumptions, simple results may be deduced which are directly applicable to the needs of the engineer. These assumptions, moreover, do not seriously vitiate the value of the exact results from the practical standpoint.

2. It is a well-known fact that many of the aeroplanes in service at the present day, especially those of the smaller types, can be broken in the air if they are subjected to certain manœuvres. This condition of affairs can only be remedied by the introduction of a new structural material which will give a strength to weight ratio about twice that for spruce. Otherwise the structural weight of an unbreakable aeroplane will be a prohibitive value.

Under these circumstances it will be clear that the term "factor of safety," as ordinarily employed by the engineer, has very little significance, being in many cases less than unity; the method of specifying strength for most conditions of flight is therefore in terms of "load factors," such "load factor" being the multiple of the load in normal horizontal flight which the structure is designed to carry without failure.

In the following the load factor of the wings with the centre of pressure in its most forward position is taken as the basis.

3. The conditions of flight which have to be considered from the standpoint of structural strength are twofold.

(*a*) The effect of a sudden change in the attitude of the aeroplane; and

(*b*) A nose dive at terminal velocity.

It will be found that if the structure is designed of sufficient strength for these two conditions, it will be able to carry the flight loads arising from any other manœuvres to which the aeroplane can reasonably be subjected.

4. Let us first consider the effect upon the main plane structure of the air loads arising under condition (*a*) above.

As long as the aeroplane is flying steadily in a horizontal path the upward load on the lifting surfaces (including the tail plane) must be equal to the weight of the complete aeroplane, including the load carried. Under this condition, therefore, the load factor is unity. Under certain circumstances this load is increased; *e.g.*, by gusts. The worst case, however, which can occur to increase the load on the supporting surfaces arises when the aeroplane is suddenly made to change its attitude from a fine to a coarser angle of incidence. Under these circumstances the loads may reach very high values for the following reason. If the aeroplane is flying steadily at a fine angle of incidence the speed must be sufficiently high to give the necessary lift for steady flight with the small lift coefficient k_L appropriate to the fine angle of incidence. When the aeroplane, by violent manipulation of the elevators is made to assume a coarser angle of incidence, the value of k_L increases at once. The speed, however, cannot drop instantaneously, and so the aeroplane has a speed corresponding to a fine angle of incidence with a lift coefficient appropriate to a coarser angle. The effect is greatly to increase the air load on the wings.

Let W = the total weight of the aeroplane.
S = the area of the main planes.
ρ = the density of the air = ·00237 at ground level.
k_L = the lift coefficient at any speed V.
k_{L_0} = the lift coefficient at stalling speed V_0.
k_{L_A} = the lift coefficient at any speed V_A where $V_A < V$.

Suppose the aeroplane to be flying steadily at a speed V and to be suddenly pulled out to an angle of incidence corresponding to a speed V_A.

Then the lift on the wings:

$$L = k_{L_A} \rho S V^2 \quad . \quad . \quad . \quad (1)$$

But for steady flight conditions at a speed V_A:

$$W = k_{L_A} \rho S V_A^2 \quad . \quad . \quad . \quad (2)$$

Dividing (1) and (2) we obtain:

$$\frac{L}{W} = \left(\frac{V}{V_A}\right)^2 \quad . \quad . \quad . \quad . \quad (3)$$

Now $\frac{L}{W}$ is a measure of the load factor which the aeroplane must have to enable it to withstand such a manœuvre as this sudden change of attitude.

In actual flight it is of course a physical impossibility to change the attitude of the aeroplane instantaneously, but in the case of a small quickly-manœuvred craft the controls can be operated very rapidly and an approximation to the loads obtained as above can be reached.

Weight considerations prohibit the use of the very high factors which would be necessary to safeguard the structure against such a manœuvre, and in actual design the figure of seven is very rarely exceeded. It will be clear, then, that the choice of a proper and suitable main plane factor is the fundamental point to be considered, and once this value has been fixed, the rest of the structure should be designed consistently with it.

5. Suppose, then, that the main plane factor N has been fixed. It is now possible to determine the maximum speed from which a sudden "pull out" will just cause failure of the structure.

Let $V_{max.}$ = this maximum or "unbreakable" speed. Then from equation (3):

$$\frac{L}{W} = \left(\frac{V_{max.}}{V_0}\right)^2$$

but:

$$\frac{L}{W} = N$$

so that:

$$V_{max.} = V_0\sqrt{N} \quad . \quad . \quad . \quad (4)$$

Thus at any speed between V_0 and $V_0\sqrt{N}$, the main planes will be unbreakable however violent the manœuvre, and the remainder of the structure should be so designed as to fulfil this condition. Above a speed of $V_0\sqrt{N}$, a sudden "pull out" will cause failure.

It should be noted that as the centre of pressure may be in its most forward position during this manœuvre the greater proportion of the load will come upon the front truss of the wings. The rear truss may, however, carry some part of the load, and must therefore also be considered for strength under these conditions. As a general rule the criterion for the strength of the rear truss, however, will not be this case, but that of a terminal velocity nose dive which is considered later.

6. Let us now consider the effect upon the tail plane and the fuselage of a sudden change of attitude which loads the main planes up to the factor N.

Let
α = the angle of incidence of the main planes corresponding to the "unbreakable" speed $V_{max.}$, α being measured from the angle of "no-lift."
β = the angle of down-wash from the main planes at this speed.
γ = the angle of incidence of the tail plane to the flight path.

Then the true angle of incidence of the tail plane is:

$$\psi = (\gamma - \beta).$$

But, to a sufficient approximation

$$\beta = \frac{\alpha}{2}$$

so that:

$$\psi = \left(\gamma - \frac{\alpha}{2}\right).$$

The angle ψ can thus be found. Assume that in order to pull out suddenly the elevators are so adjusted as to give the maximum value of the lift coefficient k^1_L on the tail plane. Since ψ is known, the value of k^1_L can be found from model tests such as those recorded in the Technical Report of the Advisory Committee for Aeronautics for 1913–14, page 141 *et seq.*

Let δ be the loading on the tail plane per square foot under this condition.

Then:

$$\delta = k^1_L \rho V^2_{max.}$$

but

$$V_{max.} = V_0\sqrt{N}$$

so that

$$\delta = k^1_L \rho V_0^2 N \quad . \quad . \quad . \quad (5)$$

Now

$$W = k_{L_0} \rho S V_0^2$$

or

$$V_0^2 = W/k_{L_0} \rho S$$

Substituting in equation (5):

$$\delta = \frac{k^1_L}{k_{L_0}} \cdot \frac{W}{S} \cdot N.$$

But $\frac{W}{S}$ = the main plane loading = Δ.

so that

$$\delta = \frac{k^1_L}{k_{L_0}} \Delta N \quad . \quad . \quad . \quad (6)$$

giving the maximum tail loading which can be applied without causing failure of the main plane structure.

7. It is now necessary to turn our attention to the case when the aeroplane is nose-diving steadily at its terminal velocity.

Under these conditions the forces on the structure consist of a heavy down load on the front truss of the main planes; a heavy up load on the rear truss; and a heavy down load on the tail plane.

It can be shown* that the tail loading required to maintain steady flight in a terminal velocity dive can be expressed by:

$$\delta_1 = \frac{\Omega \Delta U}{u}$$

where

Δ, as before is the main plain loading.
U is the area of the main planes multiplied by the chord of the main planes.
u is the area of the tail plane multiplied by the distance from its centre of pressure to the centre of gravity of the aeroplane.
Ω is a value depending partly on the cleanness of the aeroplane, but chiefly on the aerofoil section of the main planes.

A factor of safety on this loading will be necessary which we will denote by n. The relation of n to N will be discussed later. It may be noted here that n is a real factor of safety since δ_1 is a maximum possible load.

Then:

$$\delta_1 = \frac{n \cdot \Omega \Delta U}{u} \quad . \quad . \quad . \quad (7)$$

Having found δ_1, and hence the total tail load, it is a simple matter, by taking moments, to find the loads on the trusses.

8. It now becomes necessary to examine the relationship between n and N. From equations (6) and (7) it will be seen that two values for the tail loading δ and δ_1, have been obtained from the two conditions of flight.

These values can be made identical by a suitable adjustment of n, and by equating (6) and (7) a relationship between n and N can be found.

Thus:

* This question is dealt with in "Aeroplane Structures" (Pippard and Pritchard), page 48.

$$\frac{n\,\Omega\,\Delta\,U}{u} = \frac{k1_L}{k_{L_0}}\,\Delta\,N$$

or:

$$n = \frac{k1_L}{k_{L_0}}\,\frac{u}{U}\,\frac{N}{\Omega} \quad . \quad . \quad . \quad (8)$$

Now $\frac{k1_L}{k_{L_0}}$ varies somewhat with different aerofoils, but for practical purposes it is sufficiently accurate to take it as equal to unity, so that (8) reduces to:

$$n = \frac{u}{U}\,\frac{N}{\Omega} \quad . \quad . \quad . \quad . \quad (9)$$

For R.A.F. 14-wing section Ω is approximately equal to unity, and for R.A.F. 15 Ω is approximately 0·6, so that equation (9) reduces to:

$$\text{For R.A.F. 14,} \quad n = \frac{u}{U}\,.\,N \quad . \quad . \quad . \quad . \quad (10)$$

$$\text{For R.A.F. 15,} \quad n = 1.67\,\frac{u}{U}\,N \quad . \quad . \quad . \quad (11)$$

It will be noticed that the value of n is dependent on the ratio $\frac{u}{U}$. This term would only be varied in any particular aeroplane by an alteration in the tail plane area.

To retain the same degree of longitudinal stability, any tail plane reduction must be accompanied by a shifting forward of the centre of gravity of the aeroplane, and so we arrive at the interesting result that it pays not only from the stability standpoint but also from the structural, to design an aeroplane with the centre of gravity well forward.

Equations (10) and (11) give rather large values for the figure n, but it must be remembered that in most strength calculations the incidence wires in the main planes are neglected. The effect of these, however, in a nose dive, is to increase the structural strength considerably, and if they are taken into account when using the value of n given by the above equation, the result will not be a heavier structure than is customary with the present standard methods.

9. To summarise the method outlined above:—

(*a*) Fix the main plane factor N and design the whole of the main plane front truss to it.

(*b*) Determine the loads on the rear truss with the centre of pressure in its most forward position; allowing a load factor N on these loads.

(*c*) Determine the terminal velocity tail load.

(*d*) Find n from equation (9).

(*e*) Determine the main plane loads in a nose dive using the value of n found at (*d*). If the rear truss load is greater than that found by (*b*), use it for design purposes.

(*f*) Examine the front truss for down loads found at (*e*).

(*g*) Design the fuselage and tail structure for a loading δ on the tail.

The result will be a structure of consistent strength and requiring the specification of one load factor only.

THE DISTRIBUTION OF AIR PRESSURE AND WIND VELOCITY ABOUT THE FUNNEL OF A VESSEL AT SEA.

By A. P. THURSTON, D.Sc., F.R.Ae.S., M.I.A.E., A.M.I.M.E., F.R.Met.S., &c.

THE results of some experiments made by the author on the distribution of pressure around a small circular rod were published by special request in your columns on August 21, 1914. Some curious facts were then brought out which have been confirmed during the war by the National Physical Laboratory. Thus it was found with a small rod that the compression extended over an arc of only 78 deg. of the total circumference of the circle, i.e., over a little more than one-fifth of the circumference, the remaining four-fifths of the circumference being in suction. It was also found that the greatest suction occurred on the outer sides of the half of the rod facing the wind. This suction actually introduced a component force opposite to the direction of the wind, tending to drag the rod into the teeth of the wind. The reason for the head resistance of a circular rod being less than the head resistance of a square one is thereby simply explained.

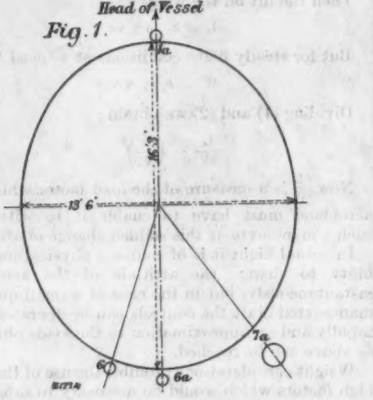
The writer wished to carry out similar experiments with large circular structures in order to ascertain whether the same conditions held for large bodies. The opportunity occurred in August, 1914, while the writer was dodging Hun cruisers in the ss. Patuca during a voyage from Panama to Port Avon, when coming to England to volunteer for service.

The writer is indebted to the courtesy of Commander E. H. Jones, master of the ss. Patuca (Elders and Fyffes, Limited) for permission to determine the pressure distribution around the funnel of this vessel by means of apparatus which could be rigged up on board.

Strict comparison between model and full-size experiment cannot unfortunately be made, because the single funnel of the ss. Patuca is not strictly circular, but on a horizontal cross-section an ellipse 16 ft. 3 in. by 13 ft. 6 in., and, moreover, the surface is obstructed by the usual vertical pipes at positions 1A, 6, 6A and 7A, as shown in Fig. 1.

The experiments were made by attaching the static of a Pitot tube to the end of a fishing rod. The Pitot tube was connected by a long tube to a Xylol micromanometer. The pressure was read in $\frac{1}{10}$ in. of Xylol, having a specific gravity of 0·86. Pressure readings were taken at the edges

CROSS SECTION OF FUNNEL OF R.M.S. PATUCA.
Head of Vessel
Fig. 1.



and centres of the rim plates forming the funnel giving 20 readings equally spaced at a height of 16 ft. above the base of the funnel. The wind was on the starboard quarter during the experiments described with reference to Figs. 2 and 3, and, as the ship's average speed was only 12·75 knots, the velocity of the relative wind was consequently low. In the case of the experiments described with reference to Fig. 4, the wind was on the starboard beam. From these diagrams it will be observed that the pressure distribution is approximately butterfly-shaped just as in the case of a small rod, although the velocity of the relative wind is small. The compression extends over an arc subtending from 77 deg. to 82 deg. The irregularities of the curves are to be explained in part by the obstruction caused by the various vertical pipes running up the side of the funnel. It would be interesting to repeat experiments of this nature around the funnel of a fast destroyer or cruiser when steaming into the wind.

One fact brought out is that quite a considerable amount of horse-power would be lost in driving the dead surface of a vessel against a head wind. The experiments could obviously be repeated to advantage over the whole of the upper structure of a vessel. In this way those portions presenting an unusual amount of head resistance would be indicated. This information would be useful when designing high-speed vessels and boats, and would doubtless enable the efficiency of designs to be improved without sacrificing the comfort or safety of the vessel. The head resistance of the superstructure of high-speed vessels is now an appreciable factor.

The results of a series of readings taken during Thursday morning, August 27, 1914, are shown plotted in Fig. 2. The ship's position at noon was 44·55 N., 22·45 W., and the true course was N. 61 E.

The direction of the wind was true south, and was estimated by the officer on the watch as from 3 to 4 at the end of the experiments.

The velocity of the wind on the top of the bridge-house at the beginning and end of the experiments was read by means of a Stewart rotary vane anemometer, and was found to be 500 ft. per minute before and 800 ft. per minute at the end of the experiment, the average wind velocity being 650 ft. per minute. The velocity of the relative wind may also be calculated from the maximum pressure on the funnel using the formula $v = \sqrt{2\,g\,h}$.

Where h is the pressure head in feet of air of the same statical temperature and pressure corresponding to the manometer reading.

g is the acceleration due to gravity in feet per second = 32·2 ft. per second.

v is the velocity in feet per second.

The barometer reading was 30·15 in. Dry bulb thermometer 73 deg. F. Wet bulb thermometer 69 deg. F. Temperature of sea 67 deg. F.

From the diagram it appears that the effect of the wind on the starboard quarter is to cause the wings of the butterfly diagram to be unequal, the rear wing being smaller than the fore wing.

Thus the suction on the fore part of the funnel approximately at right angles to the relative wind is greater than the suction on the rear portion of the funnel. The large vertical pipe at 7A does not appear to cause a considerable disturbance to the pressure distribution, but the pipes at 6 and 6A cause obvious disturbances behind.

Fig. 3 sets forth the result of another series of experiments made in the afternoon of August 27, 1914. At the beginning of the experiment the wind velocity at the top of the bridge-house was 760 ft. per minute, and at the end it was 1,050 ft. per minute. The pressure readings were taken as before at a height of about 16 ft. above the base of the funnel. The pressures at the surface are shown plotted in small circles. This diagram is similar in its main characteristics to that obtained earlier in the day and shown plotted in Fig. 2, the disturbance caused by the vertical pipes at 6 and 6A being more clearly indicated. On these readings being completed a second series were made at a radial distance of 2 ft. 9 in. from the funnel. The results are plotted with small crosses. This diagram is very interesting. It is more balanced. The effect of the disturbances are less marked. The maximum compression and suction are less, but the maximum and minimum points appear to occur at approximately the same angle. It would, in fact, appear that the wind is affected by the presence of the funnel long before reaching it and also that the wind quite outside the "run" of the funnel is nevertheless within the field of disturbance. This agrees with the results of observations made with small rods and which were previously published in your columns.

A series of readings were then made of the tangential velocity of the wind in contact with the funnel and the results are plotted by squares in Fig. 3. The characteristics of the velocity diagram are similar to and are similarly placed with respect to the pressure diagram. Thus the minimum velocity occurs at the point of maximum compression and the maximum velocity occurs at the point of maximum suction, indicating clearly that the characteristics of the pressure curves are due to a change from kinetic energy to pressure energy, and from pressure energy back again into kinetic energy. In fact the air within the field of the funnel is subjected to a Venturi meter effect.

Fig. 4 shows plotted other sets of readings of the pressure at the surface of the funnel taken on the afternoon of Friday, August 28, 1914. The readings in contact with the funnel are indicated with small circles and those at a radial distance of 2 ft. 9 in. are indicated by small crosses.

The ship's true course was again N. 61 E. The wind was more constant than on the day before, and was blowing on the starboard beam, estimated by the bridge at force 3.

The wind velocity on top of the bridge-house was 895 ft. per second at the beginning of the experiment. The ship's position at noon was 47° 13′ N, 16° 18′ W. Barometric pressure 30·21 in Temperature:

73 deg. F. dry bulb, 71 deg. F. wet bulb. Sea, 67 deg. F.

The disturbing influence of the vertical pipe at 1A is indicated by a peak to the surface pressure diagram

Fig. 2.

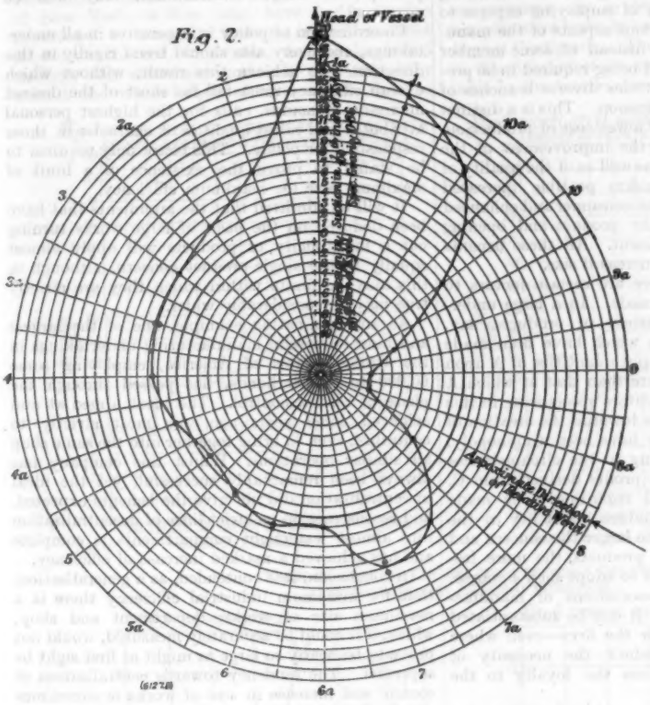


Fig. 4.

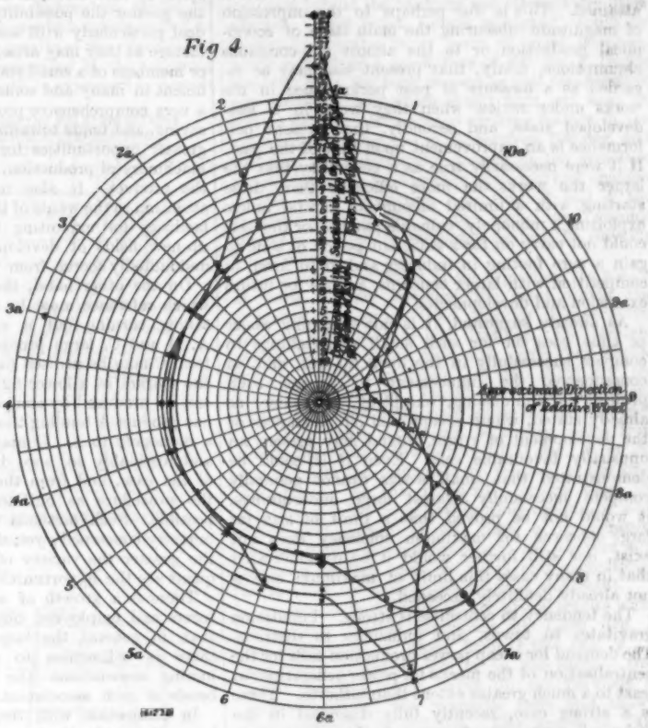
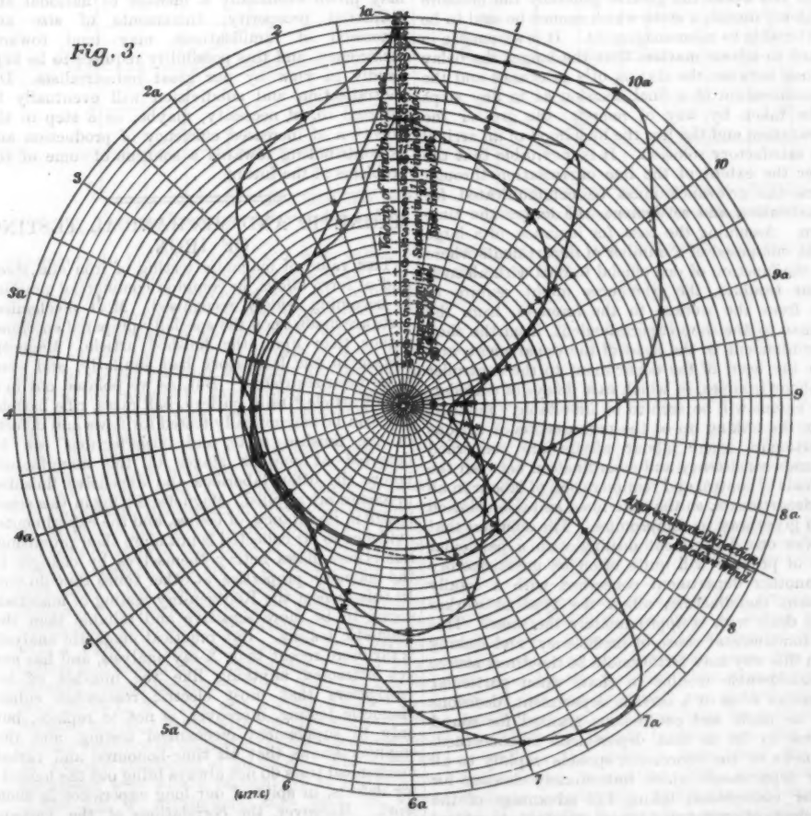


Fig. 3.



on the forward wing of the diagram. The disturbance created by the vertical pipe at 7A is indicated by a peak to the pressure distribution diagram at a radial distance of 2 ft. 9 in. The vertical pipes at 6 and 6A also appear to cause a disturbance to the latter diagram.

These experiments, although of the simplest possible nature, yield interesting results. They could with advantage be extended. Thus on a twin-funnel vessel it would be interesting to determine the interference between one funnel and the other with the wind in various quarters. The writer would be glad to hear that this work has been taken up by one of our many scientific navigating officers on a long ocean passage. It will be an interesting way of spending one's spare time during a voyage. A simple manometer in combination with the static of the Pitot tube is all the apparatus required. Greater accuracy may be obtained by the use of Professor Morris' hot wire anemometer.

It is thought that many of the facts elicited by thoroughly exploring the distribution of pressure about the whole structure of a ship at sea would be of value not only to the ship designer, but also in a marked degree to the aeroplane designer where the study of wind effects are of vital importance.

The writer is indebted to his fellow-passenger, Mr. J. P. Ellis, B.Sc., for his courtesy in assisting in rigging up the apparatus and making the readings. The writer regrets that he has been too busy during the war to comply with your correspondent's request before now.

THE SIZE OF WORKS AND THE EFFICIENCY OF CONTROL.

IN the present age of industrialism there is manifest an increasing tendency towards centralisation which finds practical expression in the direction of the amalgamation of large limited companies and in the extension of existing works and undertakings under one central organisation. Such large concerns, in a consideration of the effect of size and control, may be divided into two broad and distinct types. Factories, where a single product is manufactured are an example of the one, and works which turn out an almost bewildering variety of manufactures, typify the other. In exemplification of the former the cotton mill or the shell factory might be cited, and for multiplicity of products under one organisation some of our great munition works where in are manufactured almost everything from a ship of war to an aero engine or a machine gun, form an excellent example.

In both cases the factories would be split up into departments, but it is proposed primarily to deal with the subject from the point of view of the manufacture of a multiplicity of products under one organisation, and the question arises as to whether for maximum efficiency there is a limiting size for the scope of one organisation the size of a works, department or shop. Such a limit, if it exists, will depend, in measure, upon the nature of the control that may be operative, the necessities of the case in regard to the variety of products of manufacture, and the extent to which these two factors are co-related, since the type of control, considered quite impersonally, must be suitably equated to the nature

of the manufactures. The details of various types of control are not under discussion.

The general or casual opinion undoubtedly is that the larger the works, the factory, department or shop, the greater the efficiency of production attained. This is due perhaps to the impression of magnitude obscuring the main issue of economical production or to the almost sub-conscious assumptions, firstly, that present size may be regarded as a measure of past performance in the works under review when they were in a less-developed state, and secondly, that present performance is an improvement upon that of the past. If it were necessarily true as a generality that the larger the works the more efficient, then, those starting with a limited amount of capital unless exploiting a monopoly, valuable patents, or the like, could not carry on for a sufficient period of time to gain a sure footing in industry and so to form, in competition with larger concerns, a basis for future extension and developments.

As already suggested, it is not becoming easier as time goes on for such small undertakings to compete successfully in the open market, and, in consequence, the inducement to finance such projects is diminishing, excepting, of course, as already stated, where exceptional circumstances or the development of virgin ground may present an unusually favourable case. Even if it could be demonstrated that small works cannot generally compete successfully against large undertakings, it would not be proved that a limit of size for large concerns for maximum efficiency does not exist, nor still further would it be demonstrated that in many cases this limit of maximum size is not already definitely exceeded.

The tendency to centralise is strong. Population gravitates to towns, and industries to districts. The demand for cheap power production calls for the centralisation of the means for power generation, at least to a much greater extent than hitherto. There is a strong case, recently fully discussed in the technical press, in favour of this movement. Machines for converting energy are subject to certain limits of size dependent primarily upon existing knowledge of the laws of science, but the number of units of such maximum size which may be centralised to form one sensible unit of production is governed exclusively by the demand. The control and efficiency of power generation is independent entirely of the numbers of generating units, provided the subdivision be suitable to the load curve. With machines, environment and juxtaposition do not influence performance. In works of whatever size, electric, air, gas or hydraulic power generation should be strictly centralised, unless it be that the maintenance cost of the means or the losses consequent upon transmission be such as to counterbalance the undoubted gains of centralisation as later detailed, which case, it may be said, is extremely rare so far as factories are concerned.

With decentralisation, on the other hand, each plant must be of such a capacity as reasonably to meet the maximum demand of its consumer; and constrained, therefore, on the average to run at a fraction of full power and so at diminished efficiency, in accordance with a law applying to almost all machinery. In addition to the increased capital charges and the extra consumption of energy due to the larger size necessary, higher running costs including supervision and maintenance charges are involved. One analogy which can be drawn is certainly germane to a consideration of the main subject of size and control, and is that centralisation of such plant makes economically possible the installation of labour-saving apparatus such as coal-handling plant. It thus reduces materially the cost of production in comparison with the working expenditure on decentralised units where the first cost of such appliances would prohibit their installation.

It is assumed, in order to make comparison possible, that the relation between capital and magnitude of undertaking is relatively constant, and that the undertakings are in this respect equally sound. An undoubted gain, then, with a large undertaking is a saving in staff and in charges. The larger the power unit the more efficient, the larger the quantities of material bought, the smaller the price, so that overhead charges and macrial costs are reduced on this account with large undertakings. Since the human machine cannot be split up into fractions the larger the undertaking the greater the possibility of employing experts to deal particularly with various aspects of the manufacture as they may arise, instead of some member or members of a small staff being required to be proficient in many and sometimes diverse branches of a very comprehensive profession. This is a distinct saving, and tends towards lower cost of production, greater opportunities for the improvement of the machinery of production, as well as of the quality of the product. It also renders possible increased attention to the wants of the consumer and enhanced facilities for exploiting the product and opening up new fields of development. All these benefits undoubtedly accrue from increased size.

On the other hand, there are certain factors to which reference must be made. In a large undertaking turning out a variety of products, say, A, B and C, large profits which have been made from C may be utilised to put quantities of A upon the market at a lower figure than that at which A can be produced by competitors specialising in this one product A tending thus towards the creation of a monopoly in A. C may have been a monopoly, and justifiably so, according to the circumstances of the case, and from the profits derived from C, the procedure as outlined regarding A is made possible. Such methods induce instability in the industry concerned; yet, the larger the concern and the greater the variety of products, the more frequent are the opportunities to adopt such a course.

There is a growth of associations of manufacturers and employers, but it can be substantiated that, in general, the larger the firm—even where there is willingness to admit the necessity of joining associations—the less the loyalty to the bonds of such association.

In connection with the control of labour, the larger the works the greater generally the measure of labour unrest, a state which cannot be said to be attributable to mismanagement. It is axiomatic in regard to labour matters that the longer the delay in time between the stating of a grievance and the communication of a final decision as to any steps to be taken by way of remedy, the greater the aggravation and the less the likelihood of an arrival at a satisfactory solution. It is inevitable that the larger the extent of the line organisation through which the grievance must be communicated for consideration and settlement, the longer the time taken. Assuming the case, for instance, of a large works composed of a number of departments where it is the function of one official to deal with all such labour troubles, the grievances might require to pass from the worker to the foreman, from the foreman to the shop superintendent, from the shop superintendent to the head of the department, and from the head of the department to the controller of labour troubles, in which case delays of considerable extent will be seen to be inevitable. Furthermore, the linking up of the organisation of various departments where labour affairs are concerned demands consistency and co-ordination between the methods of control and remuneration of labour in all the departments, so that the most suitable solution often gives way to compromise. The solution that satisfies one department dealing with a particular type of product will quite often be unsatisfactory for another department concerned with a totally different manufacture, albeit the type of worker being dealt with is approximately the same. This is a fundamental cause of inefficiency, and linking up in this way may furthermore be the direct source of considerable trouble in that, when particular exigencies arise in a certain department, decisions may be made and concessions granted for sound reasons so far as that department is concerned. The news of the concession spreads rapidly to all other departments which immediately clamour for similar concessions, taking full advantage of the precedents of consistency almost inevitable to central control. The outcome is that concessions are not granted in this direct and simple way, with the consequence that the workers ultimately feel that their grievances will only receive due consideration when the total voices of discontent attain to the requisite volume. Where labour matters are concerned, it is possible that the advantage of the employment of a specialist, already conceded in principle to large undertakings, may well be negatived.

Co-ordination of policy is imperative in all undertakings, and every aim should trend rigidly in this direction. To achieve this result, without which overall efficiency must fall far short of the desired maximum demands, calls for the highest personal attributes and rarest qualities of character in those responsible for policy. This factor only requires to be stated to prove the existence of a limit of maximum size for maximum efficiency.

It will be admitted that the arguments that have been deduced on the basis of large works turning out a multiplicity of products will apply almost equally to the single-product concern, although in this case the limits within which they are strictly true may be considerably wider.

As an illuminating example, one of the largest and most successful manufacturing undertakings in the United States of America, employing some 60,000 to 80,000 hands, has passed through the phase of central control. The ideal, aimed at and achieved some years ago, was most strictly to centralise, even to bring together into the same shop all similar operations. Whilst this company has always been remarkably successful, yet the ideal of centralisation did not give the benefits expected, and reconstruction on strict lines of decentralisation into almost watertight compartments is complete and has achieved a marked increase of efficiency.

In conclusion, it is contended, as a generalisation, that for maximum industrial efficiency there is a maximum size of works, department and shop, which, if it could be accurately measured, would not prove to be nearly so large as might at first sight be supposed. The tendency towards centralisation of control and increase in size of works is sometimes essentially the outcome of personal ambition, and may prove eventually a menace to national and industrial prosperity. Increments of size and extension of ramifications, may tend towards inefficiency, and this possibility requires to be kept fixedly in view by our great industrialists. Decentralisation and subdivision will eventually be resorted to, of necessity, maybe, as a step in the direction of increased efficiency of production and as contributing towards a solution of some of the problems of the future.

MAGNETIC AND MECHANICAL TESTING OF IRON.

THE value of magnetic testing of iron and steel, and of ferro alloys, in common commercial practice is becoming widely recognised. Most mechanical tests are made upon the specially-prepared specimen rather than upon the finished article. Magnetic testing in the laboratory had similarly, and even more been restricted. But, as we pointed out in a recent article,* rails, cutlery, ball races, rifle barrels, &c., can be magnetically tested for flaws and defects in the finished state, and imperfections can be detected at various stages of the manufacture before the often laborious and expensive finishing processes are applied. Magnetic testing in this sense is still in its infancy, of course, and the experimental evidence so far collected is not more than promising. Sometimes flaws betray themselves by changes in the magnetic properties, at other times they do not. In this respect the Röntgen-ray testing of materials seems to be more sensitive and reliable than the magnetic testing. But practical magnetic analysis is far more recent than X-ray analysis, and has not yet attracted anything like the number of investigators that most electric researches enlist. Magnetic testing, moreover, is not to replace, but only to supplement mechanical testing, and the engineer knows that his time-honoured and varied mechanical tests do not always bring out the looked-for defects, in spite of our long experience in such work. Moreover, the correlations of the various mechanical tests remains difficult. Meanwhile we hear of further successes of magnetic testing. The

* See ENGINEERING, November 28 last, pages 708 to 712.

permeameters, which we illustrated in Figs. 8 and 12 of our previous article, were moved along the rail to be tested; in testing rifle barrels the testing coil was suspended and pulled up and down the vertically-mounted barrel. Messrs. Holz and Co., of New York, a firm who have had extensive experience in magnetic testing, inform us that they draw the rod, wire cable, &c., to be tested through the stationary coil. In this way they submit the whole length of wires to be fixed in aeroplanes to magnetic tests, and wire cables are bodily passed through the testing solenoid which is connected to a recording or an indicating apparatus. Particulars of the experience gained with such devices would be very valuable. It seems almost too much to expect a worn rusty cable to betray its local weakness by the fluctuations in its magnetic properties; but magnetic testing combined with careful inspection might give early warning.

At the meeting of the American Society for Testing Materials, held last June, Mr. N. J. Gebert, of New York, read a valuable paper entitled "A systematic Investigation of the Correlation of the Magnetic and Mechanical Properties of Steel," in which he showed that tests of the coercive force alone, as suggested by Mr. L. A. Wild in his paper read before the Faraday Society, are not quite sufficient to differentiate between steels of different mechanical properties. Mr. Gebert experimented with a Fahy simplex permeameter on a straight carbon tool steel (carbon percentage 1·0 to 1·15), a Swedish chrome file steel (1·19 C, 0·39 Cr), a nickel steel (0·38 C, 3·5 Ni), and a chrome-nickel steel (0·36 C, 3·5 Ni, 1·5 Cr), with the object of obtaining further evidence on magnetic changes accompanying the thermal treatment of his alloys. The annealed specimens were slowly brought up to temperature (1,630 deg. F. maximum), kept there for about 15 minutes, and then quenched; they were afterwards "drawn," i.e., heated up again slowly, kept at the maximum temperature for 30 minutes or other periods, and cooled in air—in subsequent tests, also in water. Gebert determined the maximum induction B_m, the residual induction B_r and the coercive force H_c, and, further, the tensile strength, elongation, contraction of area and Brinell hardness; the former terms were explained in our previous article, and we should point out that Gebert's temperatures are in degree Fahrenheit, whilst all temperatures were in our previous article stated in degrees Centigrade. The results of the experiments on the nickel steel are summarised in the following table I; the tensile strength is expressed in pounds per square inch, the elongation and reduction of area in per cent.:—

Fig. 1. NICKEL STEEL, SHOWING THE RELATION BETWEEN BRINELL HARDNESS & THE HYSTERESIS AREA.

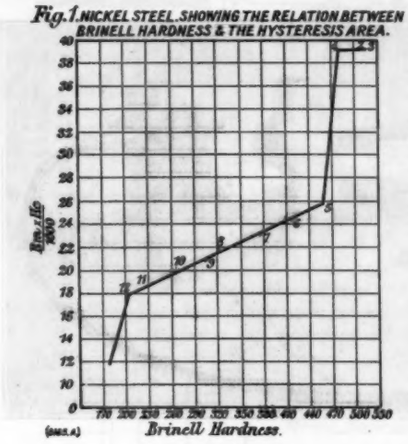
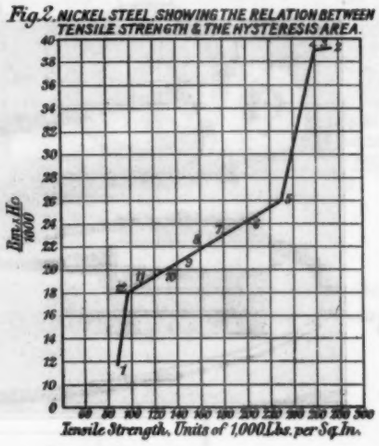


Fig. 2. NICKEL STEEL, SHOWING THE RELATION BETWEEN TENSILE STRENGTH & THE HYSTERESIS AREA.



DIAGRAMS SHOWING THE RELATION BETWEEN DRAWING TEMPERATURE AND RESIDUAL INDUCTION.

Fig. 3. NICKEL STEEL.

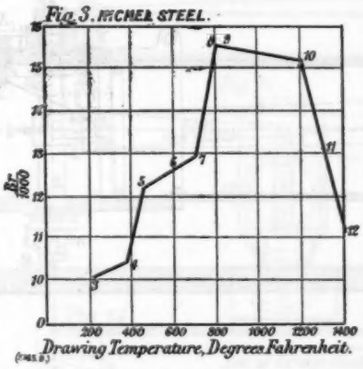


Fig. 4. CHROME NICKEL STEEL.

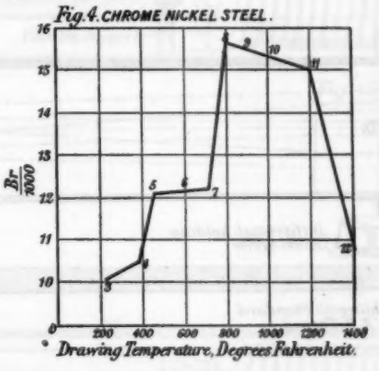


TABLE I.

No.	Draw. Deg. F.	Strength.	Elongation.	Reduction of Area.	Hardness.	B_m.	B_r.	H_c.
1	annealed	87,000	27·0	54·9	179	19,470	10,940	6·1
2	0	273,500	10·5	34·1	512	17,400	10,190	22·5
3	212	271,200	11·0	38·0	512	17,000	10,030	23·0
4	380	260,000	11·7	43·0	480	17,500	10,540	23·3
5	450	230,000	13·0	50·0	460	19,900	12,100	13·0
6	600	201,000	14·0	56·8	418	20,050	12,140	12·0
7	700	180,300	14·4	58·0	375	20,050	12,160	11·5
8	800	160,500	15·0	60·0	321	20,050	15,600	11·0
9	900	145,500	17·5	60·8	302	20,080	15,470	10·4
10	1,000	142,300	20·0	61·5	269	19,600	15,300	10·3
11	1,200	147,000	24·0	66·5	225	19,500	15,060	9·6
12	1,400	98,000	24·5	57·3	202	19,450	10,800	9·2

The chrome-nickel steel gave very similar values. In Figs. 1 and 2 the products of Brinell hardness and coercive force (each product divided by 1,000) which represent the hysteresis areas (the energies absorbed by the material when successively magnetised and demagnetised), are plotted against the Brinell hardness. On examining the table it will be seen that the Brinell hardness and the strength as well as the coercive force show the largest fluctuations; elongation and contraction also fluctuate considerably, whilst the inductions, both the B_m and the B_r vary to a much smaller degree. Yet there is a considerable increase in the two inductions between drawing temperatures of 380 deg. and 450 deg. F., while the coercive force decreases very moderately. Between these two temperatures (near 215 deg. C. or 419 deg. F., according to Honda) lies the transition point Ac; when steel is heated above that point, the cementite (less magnetisable than ferrite according to Tammann) passes out of solution, so that the intensity of magnetisation increases, whilst the hardness and strength are little affected. That point, Gebert remarked, would be important for the taper parts of roller bearings, which were given a quick draw of 400 deg. F. (being removed from the bath as soon as that temperature was reached), but which might turn out hard or soft to the file. The second striking feature in the table is the sudden rise in B_r between 700 deg. and 800 deg. F., indicating a change in the structure which does not go together with marked changes in the other properties. In Figs. 3 and 4 the B_r (divided by 1,000) of the nickel and chrome steels are plotted as ordinates against the drawing temperatures.

In section A of Table II we reproduce the results of tests of the Swedish file steel which was quenched in water from various temperatures and not submitted to any drawing. The straight carbon tool steel, we may add, gave very similar results. These materials are too hard for the ordinary Brinell test. The file steel, just mentioned, closely resembles in its composition the steel for balls and races which should not be slowly cooled from above the Acm point (about 1,650 deg. F. or 900 deg. C.) lest the cementite be rejected to the grain boundaries. As this frequently occurs when the material is lying on hot ashes while cooling, or when rolled and forged at too high a temperature, Gebert conducted experiments to see whether such incorrect cooling could be cured and magnetically be masked by subsequent thermal treatment.

In section B of Table II, are given results which show that neither annealing at 1,380 deg. F, nor quenching in water from 1,450 deg. F., of specimens cooled in air or in the furnace from 1,650 deg. F., would cover up the previous incorrect cooling; the magnetic tests still showed the material to be different. The figures of Table II were further to exemplify that the rates of cooling from drawing temperatures (after quenching in oil or water) affect the residual induction of certain steels, as they affect the impact test values, while they do not change the tensile strength nor the Brinell hardness.

TABLE II.

Treatment	B_m.	B_r.	H_c.
A.—			
1,350 deg. F. water	15,190	9,940	14·0
1,400 deg. F. water	12,890	8,880	47·8
1,430 deg. F. water	12,620	8,430	47·8
1,450 deg. F. water	12,240	8,230	48·7
1,480 deg. F. water	11,910	7,760	50·4
1,500 deg. F. water	11,390	7,440	50·4
1,530 deg. F. water	11,240	7,150	50·0
1,550 deg. F. water	11,070	6,980	48·4
1,600 deg. F. water	9,690	5,540	44·3
1,630 deg. F. water (cracked badly)	—	—	—
B.—			
As received	15,540	11,530	13·3
1,650 deg. cooled in air, annealed at 1,380 deg.	15,350	10,440	13·5
1,650 deg. cooled in furnace, annealed at 1,350 deg.	15,110	9,720	14·0
1,650 deg. cooled in air, quenched at 1,450 deg.	11,770	8,880	52·3
1,650 deg. cooled in furnace, quenched at 1,450 deg.	11,670	7,760	51·3
C.—			
1,500 deg. quenched in oil, drawn, cooled in air	19,850	12,320	16·4
1,500 deg. quenched in oil, drawn, cooled in water	19,770	11,740	16·5
1,500 deg. quenched in water, drawn, cooled in air	19,920	12,850	16·2
1,500 deg. quenched in water, drawn, cooled in water	19,870	11,340	16·3

Further experiments were made with $\frac{7}{8}$-in. bars of the chrome-nickel steel, quenched in oil or in water from 1,500 deg. F., then drawn for 1 hour at 1,160 deg., and cooled in air or in water. The results are given in section C of Table II. Changes in the residual induction are brought out, but they do not appear striking, whilst the impact tests of such materials would show very marked differences.

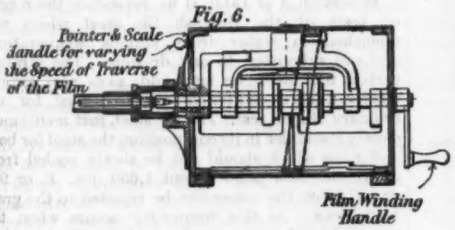
The engineer and metallurgist may object that their mechanical, chemical and microscopical tests ought to suffice. But the magnetic analyses promise

to step in where other tests fail, and they can generally be performed on the finished article and without detriment to it.

THE FEREDAY-PALMER STRESS RECORDER.

In a very interesting paper published last year in the *Revue Generale des Sciences*, M. Rabut, the eminent French engineer laid down the maxim that in bridge work actual measurement of the stresses should, wherever possible, be substituted for computations. Apart from M. Rabut's own work, relatively few satisfactory attempts have been made to determine stresses by actual observations. Of these few a very large proportion have been made with unreliable apparatus. A bridge which is traversed by a rapidly moving load vibrates somewhat violently and, unless special precautions are taken in the design of the apparatus used to measure stresses, the results are liable to vitiation by errors arising from the inertia of the moving parts.

Fig. 6.



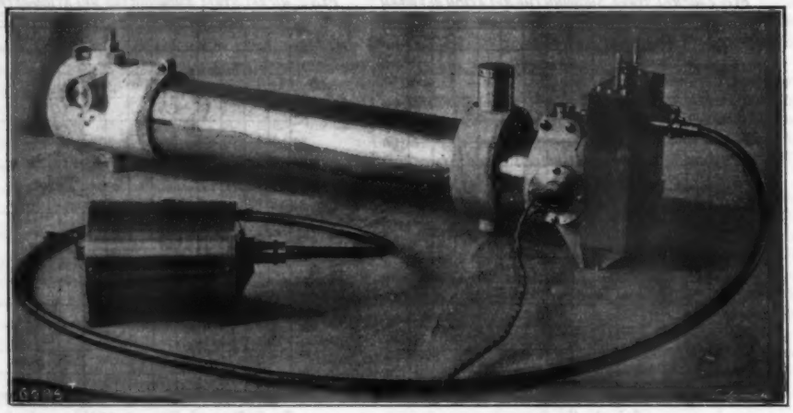


Fig. 1.

Fig. 2. Alternative Attachment for Flexible Shaft.

Fig. 4.

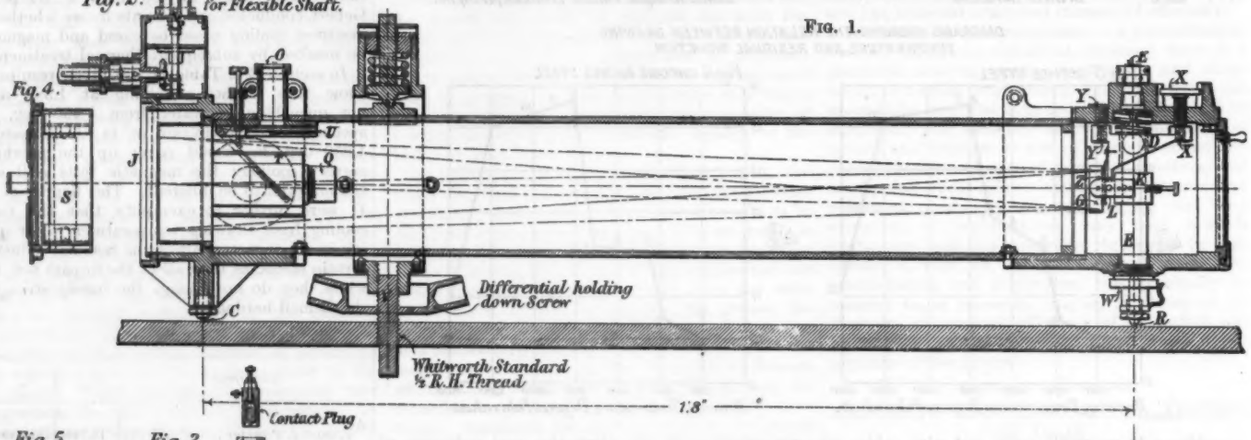
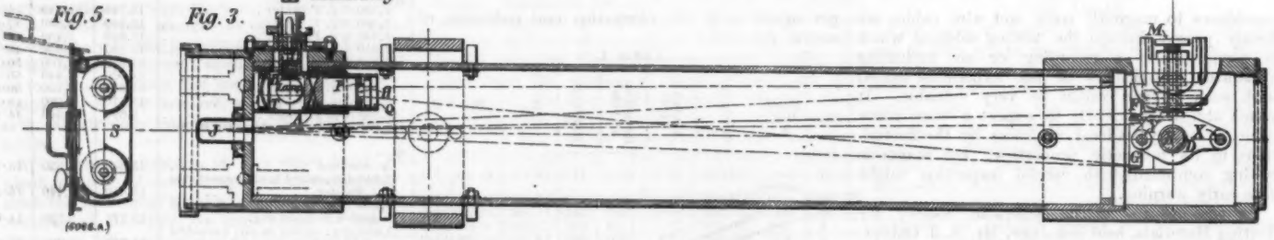


Fig. 5.

Fig. 3.



(6966.A.)

We illustrate on this and the opposite pages an instrument for determining these stresses on bridge members, which appears to be free from these inertia errors and is at the same time very portable, easily fixed in position, and provides a permanent record of the results obtained. It has been devised by Mr. H. J. Fereday, of Messrs. Rendel, Palmer and Tritton, consulting engineers, 12–14, Dartmouth-street, Westminster, and patented in the names of the inventor and Mr. F. Palmer, C.I.E.

Referring to our illustrations, a general view of this stress recorder is represented in Fig. 1, whilst details of its construction are clearly shown in Figs. 2 to 10. Its construction and mode of action will be clear on reference to the longitudinal sections, Figs. 2 and 3. It consists essentially of a light but stiff tube about 3 in. in diameter and 20 in. long. Near its left-hand end this tube is, as shown at C, provided with two feet in the form of hardened steel points. These are rigidly secured to the tube, whilst at the other end there is a third foot R, of the same character, which is rigidly mounted at the bottom of vertical leg E. This leg at its upper end is clamped into a conical seating, which makes it at this end rigid with the tube. Just below this seating the leg is thinned away, as shown, thus giving it a certain flexibility so that its foot can move slightly in a fore and aft direction. For this purpose the hole through which the leg E projects through the tube has a larger diameter than the leg. For carrying purposes, however, the clamping nut W is provided, by which the leg can be rigidly locked when desired.

A collar K is clamped to the leg E, and supports a fork which takes the pivots of a movable mirror G. A light flat spring L presses this mirror against a hardened stop Z on the opposite side of the pivots. This stop is mounted on a saddle D, which loosely embraces the leg E, and is itself supported by the adjusting screws Y and X, possible lost motion being provided for by the helical spring shown.

It will be obvious that any fore and aft motion of the foot of the leg E will result in a tilt of the mirror G. This tilt is recorded by the motion of a spot of light over a photographic film which is carried in a spool-box clamped to the other end of the tube. This spool-box is shown at S, Figs. 4 and 5. In taking a record the sensitive film is wound from one spool to the other at a suitable speed by a hand-operated winder containing a variable speed-gear, shown in Fig. 6. A flexible shaft, 5 ft. long, is used to connect the winding gear to the spool drive, and it is possible therefore for an observer to take up his station at some distance from the recorder. The light required is provided by a small electric lamp, best seen in Fig. 3. The light is passed through a collimator A, and illuminates through a lightly etched glass P, Fig. 3, the orifice H, an image of which is focussed after reflection from the mirror G on to the sensitive film. In order to provide a zero of reference, part of the light is arranged to fall upon a fixed mirror F, Fig. 3. When the member to which the instrument is secured is free from stress both reflections are caused to coincide. This is effected by the adjusting screw X already referred to. This adjustment can be made by removing the spool-box S, substituting scale N, Fig. 6, for slit J, Fig. 3, and examining the relative position of the two reflections. This method is primarily used for direct usual observation of the varying stresses, as the coincidence of the two reflections at zero load can also be ascertained without removing the spool-box. To this end a movable mirror U, Fig. 2, is provided which can, at will, be lowered into the position indicated by the dotted lines. The light rays falling on this mirror are then reflected up to the eyepiece O, and can thus be examined without removing the spool-box. The scale of magnification can be adjusted by raising or lowering the stop Z, Fig. 2, at the back of the movable mirror G. After adjustment, the saddles on which Z is mounted is clamped fast by the screw M, Fig. 3. It is thus easy to obtain a record which can be measured directly in tons per square inch by an ordinary scale.

In use the instrument is clamped to the bar to be tested. One method of doing this is illustrated at V, Fig. 2. Here a ¼-in. hole is drilled through the plate and the clamping is effected by a differential screw, as indicated. Generally, however, the instrument is held down by an ordinary clamp, Fig. 11, which does not necessitate the drilling of the plate.

A further refinement in the apparatus is illustrated in Figs. 7 to 10. As here shown, a clock is fitted inside

THE FEREDAY-PALMER STRESS RECORDER.

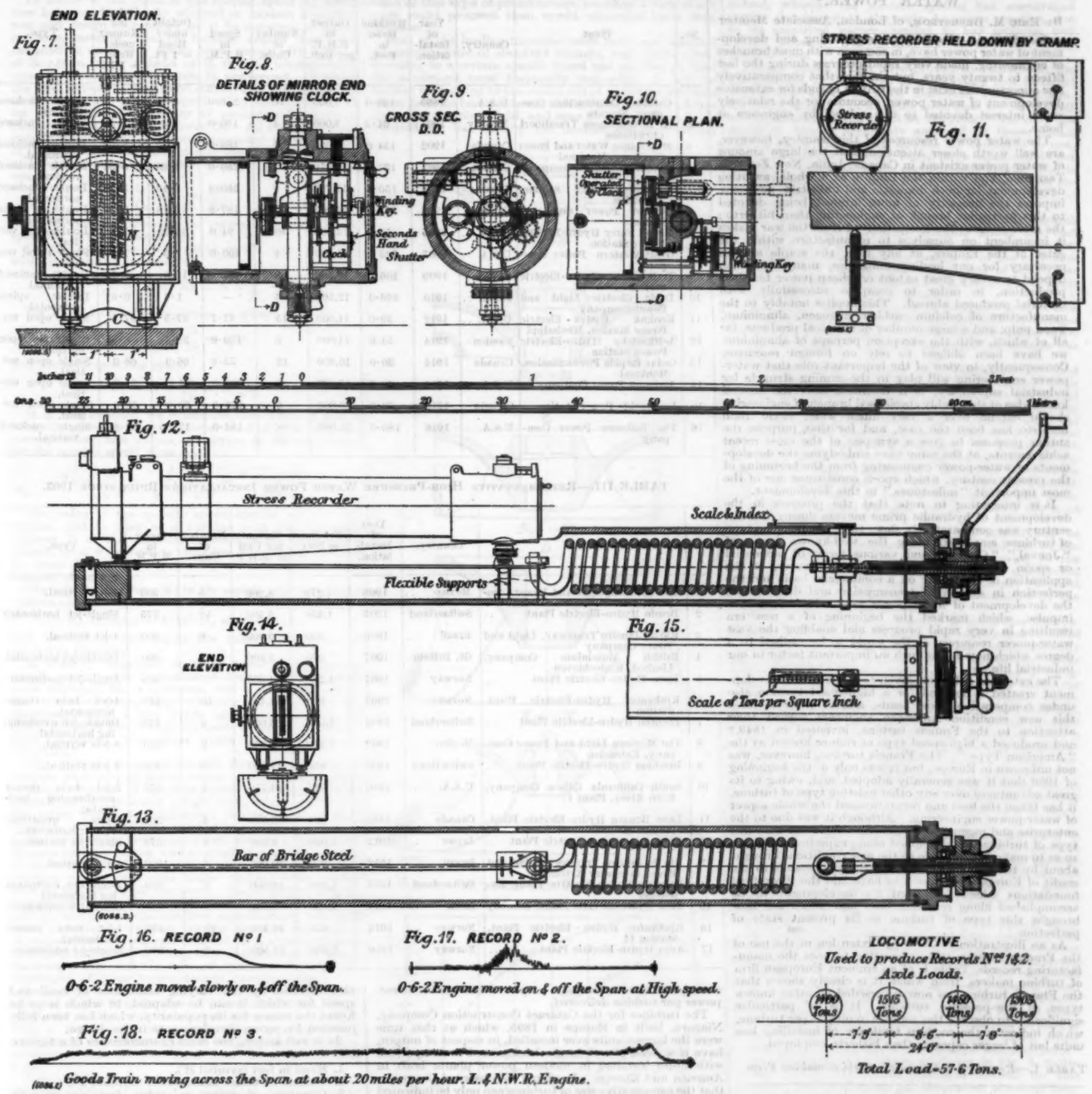


Fig. 16. RECORD No 1

0-6-2 Engine moved slowly on & off the Span.

Fig. 17. RECORD No 2.

0-6-2 Engine moved on & off the Span at High speed.

LOCOMOTIVE
Used to produce Records Nos 1 & 2.
Axle Loads.

Total Load-57·6 Tons.

Fig. 18. RECORD No 3.

(scale C.) Goods Train moving across the Span at about 20 miles per hour. L. & N.W.R. Engine.

the instrument behind the leg E and periodically moves a shutter in front of the fixed mirror F. The zero line of the record on the sensitive film is thus broken up into a series of dots representing half-second intervals.

In Figs. 16 to 18 we reproduce some records obtained, but in this case without the use of the clock. A comparison of record No. 1 and No. 2 is instructive, as it demonstrates that even in the case of this short bridge the impact is nothing like so great as is frequently assumed. The vibrations of stress were nevertheless considerable, and it was of great importance to make certain that they were not due to defects in the recording instrument. To test this the record, Fig. 19, was taken. Here the leg E was wedged, and it will be seen that a perfectly steady line was obtained. It may be added that M. Rabut in his experiments made some thirty years ago also found that stress vibrations of this kind were real and not due to instrumental errors.

The instrument is calibrated by applying it to a bar of bridge steel under a known stress. Two simple forms of calibrator, in which the stress is applied to a standard bar through a helical spring, have been designed by Mr. Fereday. One pattern is extremely portable, and makes it possible to check the adjustment of the recorder at frequent intervals during use at site. This calibrator is not illustrated, but it is of the same principle as the standard calibrator, shown in Figs. 12 to 15.

Fig. 19. RECORD No 4.

(b) Instrument placed on Bridge with its Rocking Leg Wedged.
(scale C.)

THE WELSH TIN-PLATE MARKET.—In their report for the year 1919, Messrs. Sim and Coventry, 110, Cannon-street, E.C. 4, state that America must still be looked upon as our most likely competitor, whilst Germany is probably a long way from entering the lists against us. Japan has been mentioned as a probable competitor, but it is not anticipated that she will have any surplus available for export before 1921. It was stated in September that the British export of tin plate was well over 30,000 tons per month. At the present time consumers and merchants would be only too glad to see some sign of foreign competition, for such rapid and extreme forcing of British prices as has recently taken place is distinctly unhealthy and cannot conduce to the permanent welfare of the industry. Messrs. Sim and Coventry have never had to record such a fluctuation in values as has occurred in 1919, from 31s. 6d. in July to over 50s. in December, a rise of 20s., and the price was still moving upwards. For the first four months of the year, the home trade price was under Government control, export prices being appreciably higher. The two gradually approximated, however, and when the official control ceased, at the end of April, they merged. The official price opened at 32s. 6d.; this, at the end of January, was increased to 33s. 3d., and a month later to 33s. 10½d., at which the price remained until July, when it touched about 31s. Thereafter there had been a continuous and not always gradual rise to 51s. 6d. or thereabouts, closing with a most optimistic outlook.

RECENT ADVANCES IN UTILISATION OF WATER POWER.*

By ERIC M. BERGSTROM, of London, Associate Member

Introduction.—Water-power engineering and development of water power have, in common with most branches of engineering, made very rapid progress during the last fifteen to twenty years, but the fact that comparatively few opportunities exist in the British Islands for extensive development of water power, accounts for the relatively small interest devoted to this subject by engineers at home.

The water power resources of this country, however, are well worth closer attention, and the large amount of water power existent in Canada, India, New Zealand, Tasmania, and within the Empire as a whole, awaiting development for both domestic and industrial purposes, imposes the necessity of more interest being devoted to this particular branch of engineering than hitherto; the more so since the lesson derived from the war makes it incumbent on ourselves to manufacture within the gates of the Empire, at any rate, the staple articles necessary for our leading industries, many of which depend to a very great extent on cheap power for their production, in order to compete successfully with material produced abroad. This applies notably to the manufacture of calcium carbide, nitrogen, aluminium, wood pulp, and a large number of chemical products, for all of which, with the exception perhaps of aluminium, we have been obliged to rely on foreign resources. Consequently, in view of the important role that water-power engineering will play in the coming struggle for industrial supremacy, it is desirable that the general knowledge of this highly specialised branch of engineering should extend over a very much wider circle than hitherto has been the case, and for that purpose the author proposes to give a synopsis of the most recent achievements, at the same time embodying the developments of water-power engineering from the beginning of the present century, which epoch constitutes one of the most important "milestones" in this development.

It is interesting to note that the progress in the development of hydraulic prime movers during the last century was comparatively slow, the most common type of turbines employed being the well-known types of "Jonval," "Girard," and various forms of tangential or spoon wheels. With the advent, however, of the application of electricity on a commercial basis and the perfection in system of transmission and distribution, the development of water power received a tremendous impulse, which marked the beginning of a new era resulting in very rapid progress and enabling the vast water-power resources of the world to be utilised to a degree which now forms such an important factor in our industrial life.

The extended field thus given to water-power development created a demand for a high-speed turbine also under comparatively low heads, and in order to meet this new condition American engineers turned their attention to the Francis turbine, invented in 1849,† and produced a high-speed typo of runner known as the "American Type." The Francis turbine, however, was not unknown in Europe, but it was only at the beginning of 1900 that it was generally adopted, and, owing to its great advantages over any other existing type of turbine, it has taken the lead and revolutionised the whole aspect of water-power engineering. Although it was due to the enterprise and ingenuity of American engineers that this type of turbine was developed along experimental lines, so as to make it adaptable to the new conditions brought about by the introduction of electricity, it stands to the credit of European engineers to have laid the theoretical foundations which permitted its development to be accomplished along scientific lines and which has now brought this type of turbine to its present state of perfection.

As an illustration of the rapid extension of the use of the Francis turbine, it is interesting to note the manufacturing records, Table I, of an eminent European firm of turbine makers, from which it is clearly shown that the Francis turbine has now superseded all other known types of low-pressure turbines. It is of particular significance to observe the increase in output per turbine, which indicates the modern tendency of installing less units but of larger capacity than hitherto employed.

TABLE I.—*Record of a European Turbine-making Firm.*

Period.	Jonval No.	Girard No.	Francis No.	Tangential Wheels No.	Total B.H.P.	B.H.P. per Turbine.
1850–94	904	883	7	623	179,256	74·2
1895–99	72	99	99	232	114,818	229·1
1900–04	8	16	464	309	390,252	495·1
1905–09	—	—	457	236	836,582	1,116·0
1910–14	—	—	375	219	1,162,380	1,056·8

This last-mentioned feature of modern hydro-electric development is also evident from a perusal of Table II, on this page, in which the most representative installations built since 1895 have been tabulated; but perhaps an even more striking illustration is furnished by figures recently published by an American manufacturer, who commenced the manufacture of the Francis turbine in 1895, and since that date has completed installations with an aggregate output of 1,683,720 brake horse-power, corresponding to an average output of 8,000 brake horse-power per turbine delivered.

The turbines for the Cataract Construction Company, Niagara, built in Europe in 1895, which at that time were the largest units ever installed, in respect of output, have now been placed in the background in comparison with units installed in modern power plants both in America and Europe. It should be observed, however, that the comparative size of turbines can only be indicated by their output under an equal head, and for the purpose of comparison, the various outputs under the unit head of 1 ft., have been tabulated, which shows that the largest turbines in the world in respect of dimension are those erected at the Cedar Rapids in Canada, which installation will be reverted to later. By way of comparison, Table III, above, shows the most representative high-pressure turbine installations installed during the last fifteen years.

According to broad principles, the turbines are classified in two categories, namely, reaction and impulse turbines.

The Francis turbine belongs to the former, and the high-pressure impulse turbine—or more familiarly known as "Pelton Wheel"—belongs to the latter category, and being the only types of turbines now employed in modern water-power development, it is unnecessary to deal with any other type except as far as historical interest is concerned.

FRANCIS TURBINES.

The Francis turbine, named after its American inventor, has a runner of the radial inflow type, the water entering the runner with a velocity corresponding to only a portion of the head, approximately half, and the remaining pressure-energy is utilised to accelerate the water during its passage through the runner. It is characterised by the varying conditions of head and speed for which it can be adapted, in which is to be found the reason for its popularity, which has been fully justified by recent developments in its design.

As is well known, the main characteristics of a turbine are:—

1. Head in feet (symbol H).
2. Output in brake horse-power (symbol P).
3. Quantity of water in cubic feet per minute (symbol Q).
4. Speed in revolutions per minute (symbol N).

If we assume that under the given head of H ft. the characteristics of the turbine are P, Q and N respectively the corresponding characteristics for the unit head of 1 ft. would be:

$$\frac{P}{H\sqrt{H}}, \quad \frac{Q}{\sqrt{H}}, \quad \frac{N}{\sqrt{H}},$$

which are termed the unit speed, unit quantity of water, and unit output for any turbine.

This turbine, under the head of H ft. would consequently have the following characteristics:—

$$P_s = \frac{P\,H_s\sqrt{H_s}}{H\sqrt{H}}, \quad Q_s = \frac{Q\sqrt{H_s}}{\sqrt{H}}, \quad N_s = \frac{N\sqrt{H_s}}{\sqrt{H}}$$

The above conditions apply only to turbines of the same diameter and design, and in order to compare turbines of different diameters and operating under entirely different conditions, the factor known as the "specific speed" has recently been introduced (symbol N_s), which term indicates the speed any given turbine

TABLE II.—REPRESENTATIVE WATER POWER INSTALLATIONS BUILT SINCE 1895.

No.	Plant.	Country.	Year of Installation.	Working Head in Feet.	Output in B.H.P. per Unit.	Number of Units.	Speed in R.P.M.	Output under Head = 1 Ft.	Output per Runner under Head = 1 Ft.	Type.
1	Cataract Construction Company, Niagara	U.S.A. ..	1895	136·0	5,000	10	250·0	3·15	1·575	Double enclosed vertical.
2	A. B. Glommens Traesliberi, Christiania	Norway	1901	64·5	3,000	4	150·0	5·8	5·8	Single enclosed vertical.
3	Shawinigan Water and Power Company, Montreal	Canada	1902	134·0	6,000	1	180·0	3·87	1·94	Double enclosed horizontal.
4	Canadian Niagara Company	Canada	1903	133·0	10,250	3	250·0	6·68	3·34	Double enclosed vertical.
5	Svalgfors Power Station, Notcoiden	Norway	1904	150·0	11,750	3	250·0	6·40	3·20	Double enclosed horizontal.
6	Ontario Power Company, Niagara	Canada	1904	175·0	12,000	—	187·5	5·18	2·59	Double spiral horizontal.
7	McCall Ferry Hydro-Electric Power Station	U.S.A. ..	1905	53·0	13,500	10	94·0	35·00	17·5	Double open vertical.
8	Great-Western Power Company	U.S.A. ..	1907	525·0	18,000	4	400·0	1·5	1·5	Single spiral vertical.
9	Trollhattan Hydro-Electric Station	Sweden	1909	106·0	12,500	8	187·5	11·5	5·75	Double enclosed horizontal.
10	Tokio Electric Light and Power Company	Japan ..	1910	396·0	12,500	6	—	1·6	0·8	Double spiral horizontal
11	Keokuk Hydro-Electric Power Station, Mississippi	U.S.A. ..	1912	39·0	14,000	15	57·7	57·5	57·5	Single open vertical.
12	Aelfkarleby Hydro-Electric Power Station	Sweden	1914	54·0	14,000	5	150·0	35·4	8·85	Quadruple open horizontal.
13	Cedar Rapids Power Station, Montreal	Canada	1914	30·0	10,800	12	55·6	66·0	66·0	Single open vertical.
14	Alabama Power Company ..	U.S.A. ..	1914	68·0	17,500	6	100·0	31·0	31·0	Single open vertical.
15	Laurentide Power Station ..	Canada	1915	76·0	20,000	6	120·0	30·0	30·0	Single open vertical.
16	The Tallassee Power Company	U.S.A. ..	1916	180·0	31,000	—	154·0	12·85	12·85	Single enclosed vertical.

TABLE III.—REPRESENTATIVE HIGH-PRESSURE WATER POWER INSTALLATIONS BUILT SINCE 1903.

No.	Plant.	Country.	Year of Installation.	Net Head in Feet.	Output per Unit in B.H.P.	Number of Units.	Speed in R.P.M.	Type.
1	The Mexican Light and Power Company, Necaxa	Mexico ..	1903	1,279	8,200	6	300	4-jet vertical.
2	Brusio Hydro-Electric Plant ..	Switzerland	1905	1,350	3,500	12	375	Single-jet horizontal.
3	Rio de Janeiro Tramway, Light and Power Company	Brazil ..	1906	950	9,000	6	300	4-jet vertical.
4	British Aluminium Company, Limited, Kinlochleven	Gt. Britain	1907	900	3,300	11	300	Double-jet horizontal.
5	Tysse Hydro-Electric Plant ..	Norway ..	1907	1,260	4,800	7	375	Single-jet horizontal.
6	Bjukanfos Hydro-Electric Plant, Station I	Norway ..	1908	930	14,450	10	250	4-jet twin runner horizontal.
7	Loentch Hydro-Electric Plant ..	Switzerland	1908	1,075	6,000	4	375	Double-jet overhanging horizontal.
8	The Mexican Light and Power Company, Extension	Mexico ..	1909	1,279	16,000	2	300	4-jets vertical.
9	Biasbina Hydro-Electric Plant ..	Switzerland	1909	850	11,000	3	300	4-jets vertical.
10	South California Edison Company, Kern River, Plant I	U.S.A. ..	1910	865	10,750	4	250	2-jet twin runner overhanging horizontal.
11	Lake Bunzen Hydro-Electric Plant, Station II	Canada ..	1912	395	13,500	3	200	8-jets quadruple runner horizontal.
12	Kinugawa Hydro-Electric Plant ..	Japan ..	1912	1,050	6,000	6	375	Single-jet horizontal.
13	Rio de Janeiro Tramway, Light and Power Company Extension	Brazil ..	1912	950	20,000	2	300	4-jets vertical.
14	Loentch Hydro-Electric Plant Extension	Switzerland	1913	1,150	16,000	1	300	Double-jet overhanging horizontal.
15	Tata Hydro-Electric Plant, Bombay	India ..	1914	1,650	13,500	6	300	Single-jet horizontal.
16	Bjukanfos Hydro-Electric Plant, Station II	Norway ..	1914	830	16,400	10	250	4-jet twin runner horizontal.
17	Aura Hydro-Electric Plant ..	Norway ..	1916	2,350	23,500	6	250	Single-jet horizontal.

* Paper read before the Institution of Mechanical Engineers, on Friday, January 23, 1920.

† J. B. Francis Lowell, Hydraulic Experiments, Boston, 1855.

would run at when operating under the unit head of 1 ft. and having an output of 1 brake horse-power.*

To arrive at the value of the specific speed N_s which now has been universally adopted in modern classification and design of runners, let it be assumed as in the previous instance, that a turbine runner has been designed to develop P brake horse-power with a speed of N r.p.m. under a head of H ft., the corresponding quantity of water being Q cub. ft. per second. If we let the head remain constant and conceive all the dimensions to be varied in exact proportion to the diameter D, we can obtain any number of geometrically-identical runners with a varying diameter D_x. All the areas of the runner would vary in direct proportion to the square of its diameter, and consequently the quantity of water and output would vary in the same proportion, and we can write :—

$$\frac{Q}{Q_x} = \frac{P}{P_x} = \frac{D^2}{D^2_x}$$

where the index X denotes the values of P and Q corresponding to the diameter D_x.

On the other hand the speed would vary inversely with the diameter, and hence :

$$\frac{N_x}{N} = \frac{D}{D_x} \text{ or } N_x = N \times \frac{D}{D_x}$$

For $P_x = 1$ brake horse-power, we write :

$$P = \frac{D^2}{D_1^2} \text{ or } \frac{D}{D_1} = \sqrt{P}$$

and the corresponding speed :

$$N_1 = N \times \frac{D}{D_1} = N \sqrt{P}.$$

If in this formulæ we substitute the values N and P being the speed and output under head of H ft. with the corresponding unit values, we arrive at the expression for the specific speed, thus :—

$$N_s = \frac{N}{\sqrt{H}} \times \sqrt{\frac{P}{H \sqrt{H}}} = \frac{N \times \sqrt{P}}{\sqrt[4]{H^5}}.$$

The value of the specific speed applies only to one runner, and in case of a turbine with two or more runners P in the formulæ represents the output per runner, or if P represents the total output the value of N_s must be divided by the square root of the total number of runners.

The relation between N_s in the metric and foot-pound system can be expressed through the following formulæ :

$$N_s \text{ (metric)} = 4{\cdot}447\ N_s \text{ (foot-pound)},$$

and throughout this paper the metric equivalent is quoted in brackets.

It is easily recognised that the value of the specific speed, owing to the limitation of design consistent with good efficiency has a minimum and a maximum value, the minimum being approximately 11 (50), and the maximum, only a few years ago, approximately 75 (330), although recent improvements in design of runners have advanced this latter value to approximately 100 (450).†

Fig. 1 shows diagrammatically the various forms of runners with corresponding values of the specific speed, A being a runner of the slow-speed type using a small quantity of water under a high head, whereas E shows the latest design of high-speed runner using a large quantity of water under a low head.

It has already been mentioned that the high-speed Francis turbine runner was evolved in America by way of experiment, and was made a prototype for standard turbines which were sold under various trade names once so familiar to all engineers. The standard turbine was admirably suited to small water-power installations, and on account of standardised manufacture, was sold at an exceedingly low cost, but the fact that the method of standardisation was not founded on a strictly theoretical basis militated for a long time against improvements in design and manufacture of turbines suitable for conditions of large hydro-electric developments.

In Europe, on the other hand, as soon as the favourable features of the Francis type of turbine had been recognised, its design was developed along scientific lines with a view to utilising, under the most favourable conditions, the great natural water-power resources existent to meet the growing demand for cheap power in bulk.

The individuality in design and precision in workmanship created by this method, in addition to the established practice of designing each turbine to suit the existing conditions in each particular installation, paved the way for utilising water power on a very much larger scale than that at first anticipated. It is significant to note that the first large hydro-electric plant installed at Niagara in 1895 was built in Switzerland, and was followed by several larger plants, which fact, perhaps, brought home to American manufacturers the superiority of the European practice and caused leading manufacturers in the United States to adopt this method.

The many advantages which were undoubtedly offered by the standardisation of turbines were, however, fully recognised in Europe, and in the value of "specific speed" was found the basis for a method of standardisation which permitted the manufacture under more advantageous commercial conditions, having due regard at the same time to efficiency and high standard of workmanship.

From the foregoing remarks it will no doubt be appreciated what an important link this exchange of ideas between the two Continents has been in the development of this type of prime mover, enabling a very much more rapid progress than would otherwise have been the case.

Most of the leading manufacturers have now adopted the manufacture of standard runners, each series corresponding to a certain specific speed and selected to meet the conditions most frequently met with. It will be realised that owing to the multitude of varying conditions which have to be considered, this system may not always cover the complete field, and spec al designs have to be resorted to, but usually the modern standard runner

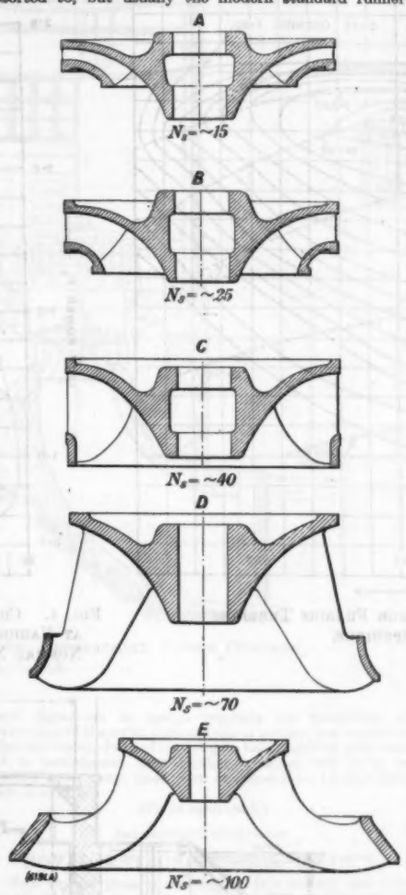


FIG. 1. RUNNERS FOR FRANCIS TURBINES.

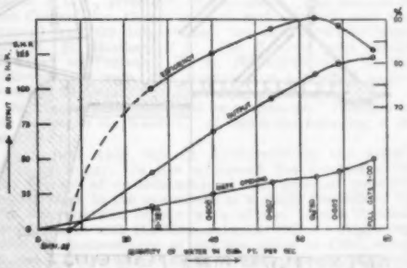


FIG. 2. TEST RESULTS OF FRANCIS TURBINE DESIGNED FOR HEAD H = 17·3 FT. OUTPUT P = 124 B.H.P. SPEED N = 187 R.P.M. SPECIFIC SPEED = N_s = 59.

covers such a wide range that in most cases where no abnormal conditions are imposed, they can be used with great advantage.

One very important factor in connection with the modern standard turbine is the exhaustive tests to which each series has been subjected, and consequently a full knowledge of its efficiency and other characteristics is available, making it possible to predict with the greatest accuracy its behaviour under a variety of conditions and enable the selection of a runner which will most efficiently meet a given set of requirements.

It is on these improved methods of systematic tests and correct designs that the standardisation of the modern turbine has been based and developed, and is by no means synonymous with the earlier attempt of standardisation, where the manufacturer lacked the knowledge of the chief characteristics of the turbine, with the result that the turbines were very often installed under conditions for which they were not suitable; indeed, whereas the modern system has encouraged further developments, the early American practice, due to its empirical nature, tended to bar progress and render abortive every effort of development along rational lines.

Testing plants which have proved so valuable in the development of the design of runners are now installed within the works of most European turbine manufacturers, although in America most tests are carried out at the famous testing plant at Holyoak. Not only are standard runners accurately analysed on these testing plants, but all new special designs are subjected to test, and in the case of turbines, whose large capacities do not permit of testing, accurate geometrically-similar models of small diameter are made for testing purposes, and the results represent very accurately the performance of the master runner.

The importance of proper tests and rational research work, where the conditions bringing about the best results can be definitely ascertained, has perhaps in few instances manifested itself so clearly as in the evolution of the Francis turbine, the development of which has only been possible by exhaustive trials and by intelligent application of the results so obtained.

As a point of interest, in view of the importance of this subject, to realise fully the limitations and advantages of various types of runners, a brief reference will be made to the tests and the methods employed to analyse the results.

The tests for the purpose of investigating the chief characteristics of runners in order to determine their performance under a varying set of conditions are carried out in specially prepared testing flumes, the turbine being generally placed in a vertical position with the runner suspended from a ball suspension bearing to reduce the mechanical losses to a minimum. A Proney brake is usually employed for recording the output, and the quantity of water measured by means of an accurate weir, by floating vane in a specially-prepared channel, or by a large tank of known dimensions; the latter practice is not often adopted, but is certainly the most accurate method.

These tests are distinct from, and should not be confused with, the commercial tests carried out *in situ* after the erection of a plant, in which, owing to the entrance losses in the casing and larger mechanical losses due to friction in bearings, the efficiency recorded may fall considerably below the values obtained by the same runner at the testing plant.

The author considers it necessary to make this observation, as it is often the case that the efficiencies obtained from turbines of different makes are indiscriminately compared without reference to the conditions under which the test has been carried out. It is easily recognised that the efficiency obtained from a particular turbine, for instance at the Holyoak testing flume, where efficiencies of over 90 per cent. have been obtained, is by no means commensurate with the efficiency obtained from a plant under actual working conditions when a maximum efficiency of 86 per cent. would be considered exceedingly good; the former owing to the ideal conditions under which the test has been carried out representing as nearly as possible the hydraulic efficiencies of the runner only, whereas in the latter case the total efficiency of the plant under commercial load is represented.

During the tests in the testing flume the head is maintained as constant as possible, and the output and efficiency obtained at the various speeds and gate opening are plotted in diagrams with speeds as abscissæ and the output and efficiencies as ordinates, when a "speed-power" and a "speed-efficiency" curve are obtained for a number of different gate openings.

The power and efficiency curves at normal speed, which is the speed for which the runner has been designed, and if correctly designed the speed at which the maximum efficiency is obtained, can now be plotted in a diagram as shown in Fig. 2. This diagram has been computed from a test at Holyoak with a runner of a specific speed of 59 (260) and gives the values of output and efficiency of the runner under a head of 17·3 ft. at a normal speed of 187 r.p.m.* This diagram, however, cannot be used to determine the behaviour of the runner under other conditions, and a diagram of the "general characteristics" of the turbine must be drawn as shown in Fig. 3, representing one of the several methods devised for this purpose. In this diagram all the values obtained from the tests have been reduced to the values corresponding to the unit head of 1 ft. with the unit speed as abscissæ and the power as ordinates, the efficiency being plotted as continuous parabolic curves.

The method of drawing these curves is as follows : The speed-power curves under the unit head and at the various gate openings are first drawn, as shown in dotted lines on the diagram. From the speed-efficiency curves we find the speeds at which, with the different gate openings, the same efficiencies are obtained and mark these speeds on the corresponding speed-power curves and draw a continuous curve through the points so obtained. This process is repeated to cover the full range of efficiencies obtained from the test and the diagram is completed.

The use of the diagram is just as interesting as it is simple. Assume that the turbine as represented by this diagram is selected to work under a head of 25 ft., the power developed at full gate would then be :

$$P = 1{\cdot}73 \times 25 \times \sqrt{25} = 216{\cdot}25 \text{ b.h.p.}$$

and the normal speed :

$$N = 45 \times \sqrt{25} = 225 \text{ r.p.m.}$$

* Dr. Camerer : "Grundriss der Turbinentheorie," 1903.

† S. J. Zowski : "Some Recent Tests of High-Power, High-Speed Turbines," *Engineering Record*, December, 1914.

* C. W. Larner, Trans. Am. Soc. of C.E., vol. lxvi, 1910.

and the efficiencies the same as those shown in the diagram for the normal unit speed of 45 r.p.m.

Assuming, however, that it is required for some reason that the turbine should run at a speed of 250 r.p.m. instead of 225, the corresponding unit speed would be :

$$250 \div \sqrt{25} = 50 \text{ r.p.m.}$$

The efficiency corresponding to this new condition of speed can be directly read off from the diagram, which shows that the increase of speed to 250 r.p.m. for this particular turbine would entail a considerable loss of efficiency, the values being :—

	Per Cent.
1·00 gate	82·5
0·883 gate	87·0
0·750 gate	85·0
0·667 gate	81·5
0·500 gate	74·0

At normal speed, the efficiency would have been :—

	Per Cent.
1·00 gate	84·0
0·883 gate	88·0
0·750 gate	90·0
0·667 gate	87·5
0·500 gate	82·0

On the other hand, assume that the speed of 225 r.p.m. is kept constant by means of a governor, and that the head is increased to say, 36 ft., the unit speed would then be :—

$$225 \div \sqrt{36} = 37{\cdot}5 \text{ r.p.m.}$$

and from the diagram we find that the unit power at full gate is 1·7, corresponding to an output of $1{\cdot}7 \times 36 \times \sqrt{36} = 367{\cdot}2$ brake horse-power. This particular turbine, represented by the characteristic diagram referred to, would be known by its normal unit speed. $N_1 = 45$ and unit power at full gate $P_1 = 1{\cdot}73$, corresponding to the specific speed $N_s = 45 \times 1{\cdot}73 = 59$ (260).

By way of comparison a similar diagram of another type of runner is given in Fig. 4.

The selection of the proper type of runner and the determining of the most suitable speed of a plant requires a great deal of consideration and cannot possibly be adequately analysed within these brief pages, but the foregoing *resume* of the evolution of the Francis turbine, together with the fundamental principles and essential facts relating to various designs of runners, enables us to appreciate fully the extent and importance of recent advances in the design of "high-capacity" runners and the value of their application in connection with low head power developments.

Reference has already been made to the effect that early attention was paid to increasing the unit speed of runners, the value of which became more apparent with the introduction of direct turbine-driven generators. Considerable study, both theoretical and experimental, has been devoted to this subject, and all attempts at improvements in design of runners during recent years have been in the direction of increasing the maximum value of the specific speed so as to secure a larger output under a given head and speed, or conversely to obtain the highest possible speed for a given head and capacity.

Only nine years ago these conditions could only be obtained at the expense of efficiency, which was particularly marked with fractional gate openings, and a strong current of adverse opinion existed against any attempt to increase the specific speed on account of the unsatisfactory characteristics of this type of turbine which would militate against its commercial utility.

The maximum value of the specific speed obtained at that time was approximately 75 (330 metric system), and Fig. 5, below, represents the maximum efficiencies obtained with runners of various values of specific speed and fairly represents the position at that date.*

Since this time, however, great strides have been made in the development of the high-capacity runner, made possible by the application of the advanced knowledge of the conditions as the result of systematic tests and theoretical investigations. In this respect much credit is due to American engineers, by whom a number of notable installations have recently been carried out, employing turbines with a specific speed of approximately 95 with most gratifying results as regards efficiency. It is now possible to obtain runners of a specific speed of even 100 together with even higher

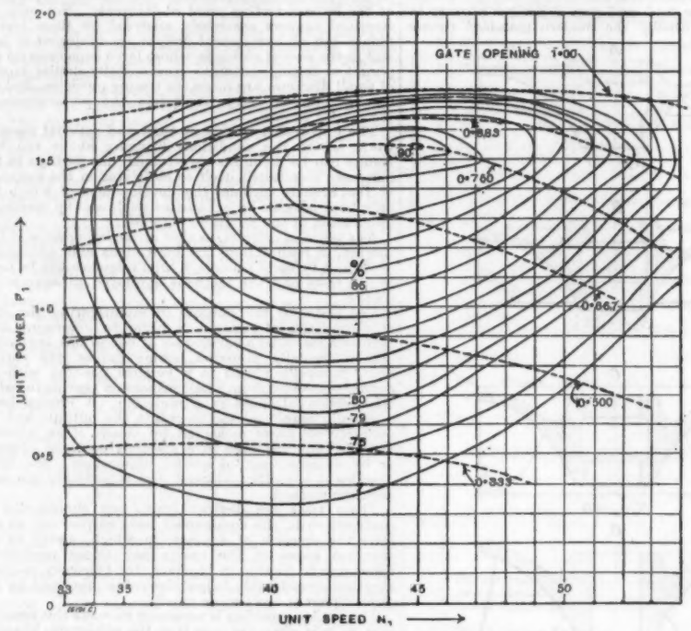


FIG. 3. CHARACTERISTIC CURVES FOR FRANCIS TURBINES AT VARIOUS GATE OPENINGS.

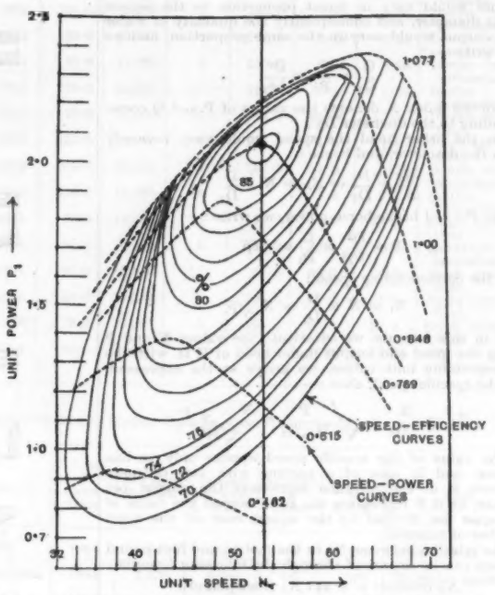


FIG. 4. CHARACTERISTIC CURVES FOR FRANCIS TURBINE AT VARIOUS GATE OPENINGS. NORMAL $N_1 = 53$ R.P.M NORMAL $N_s = 78.5$.

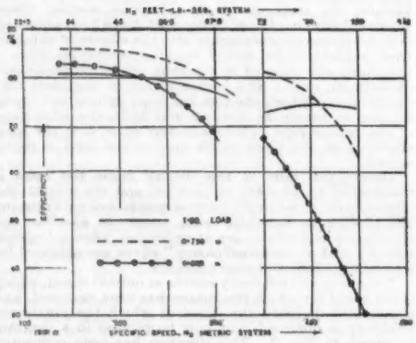


FIG. 5. DIAGRAM OF EFFICIENCIES OBTAINED FROM FRANCIS TURBINES AT VARIOUS SPECIFIC SPEEDS, 1909.

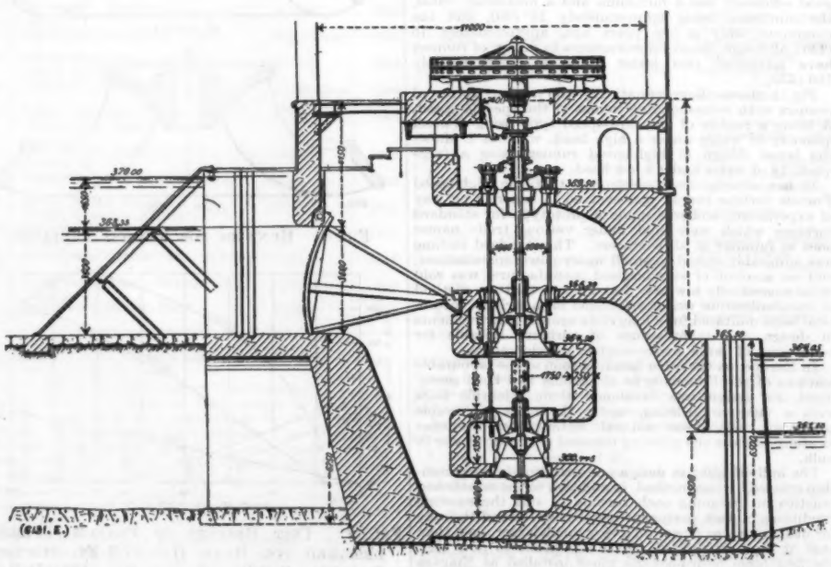


FIG. 6. CROSS SECTION OF POWER HOUSE AT CHEVRES, GENEVA.

* W. Wagenbach : "Zeits. für das Gesamte Turbinenwesen, May, 1909.

RECENT ADVANCES IN UTILISATION OF WATER POWER.

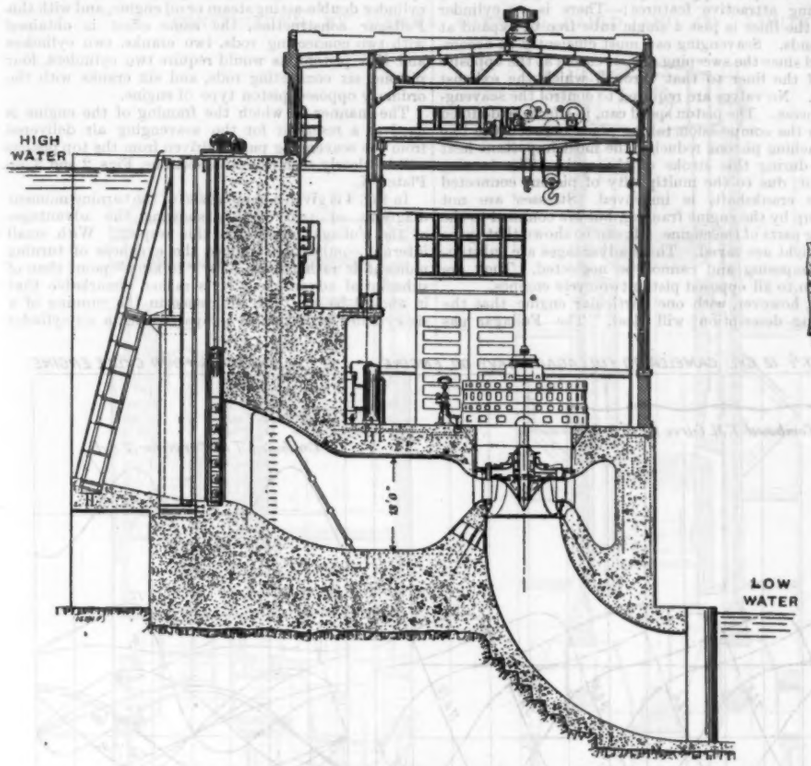


FIG. 7. CROSS-SECTION OF POWER HOUSE, APPALACHIAN POWER COMPANY, NEW RIVER, U.S.A.

maximum efficiencies than secured previously with a specific speed of very much lower value and with only comparatively small sacrifice in efficiency at part gate.

The development of the high-capacity runner has had a far-reaching effect on the economical arrangement of units for low-head plants, in addition to obviating many inherent disadvantages in the arrangement of two or more runners on a common shaft, a practice which was adopted to secure a high speed in order to effect a reduction in the initial cost of directly-driven generators. To cite an instance to demonstrate this point more vividly, reference is made to Fig. 6, showing the power station at Chevres, near Geneva. This plant, erected during 1890–98, consists of 15 Jonval turbines of the multiple-runner type, each unit having an output of 1,200 h.p., under a maximum head of 26·5 ft. and a speed of 120 r.p.m., although the five units first installed had a speed of only 80 r.p.m. If this plant were built to-day and equipped with high-capacity Francis turbines, a single runner turbine at 120 r.p.m. would give an output per unit of 2,500 h.p., or conversely with an output of 1,200 brake horse-power, the maximum speed would be approximately 175 r.p.m. With each unit consisting of a double Francis turbine, a maximum output of 5,000 brake horse-power would be secured at a speed of 120 r.p.m., or with the original output of 1,000 brake horse-power a speed of 290 r.p.m. would be obtained.

This example indicates sufficiently the great value of this latest development in the enormous saving effected in the total cost of the plant, not only on account of a lesser number of units being necessary, but also due to the reduced size of the buildings and foundations. A striking contrast is offered by Fig. 7, showing a section through the power-house of a modern vertically-arranged turbine plant, which cannot fail to illustrate the compactness in design and less foundation work as compared with the previous plant.

Although European engineers have been far more conservative in the adoption of runners with high specific speed, the maximum being 80 (350) as installed at present, test runners have been constructed up to a specific speed of 160 (750) with fairly good results.*

Fig. 8 shows a design of runner recently constructed by Escher Wyss and Co., which under official efficiency tests gave exceptionally good results at varying speeds corresponding to a specific speed of from 85 to 112 (375 to 500). The arrangement of this new type of turbine is seen from the figure, the main feature being the large space between the guide vanes and the entrance edge of the runner. Hitherto the fundamental idea in all designs of turbines has been to allow a minimum of space between the guide vanes and runner, and this new departure in design suggests the possibility of reverting to the axial Jonval type of runner, but retaining the convenient form of wicket gate for regulation purposes. It is anticipated that further progress will soon be recorded on these lines, but at present no further data are available.

(To be continued.)

* H. Th. Holm, "Moderna Vattenturbiner," Teknisk Tidskrift, Stockholm, July, 1914.

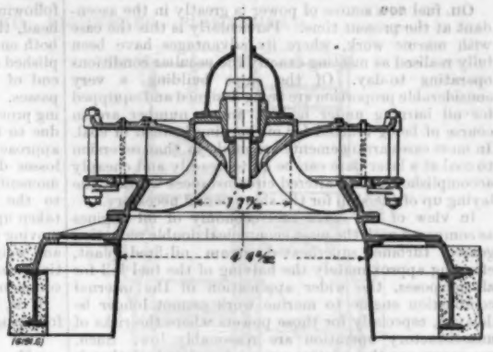


FIG. 8. NEW TYPE OF TURBINE. (ESCHER WYSS.)

ROYAL METEOROLOGICAL SOCIETY.

THE annual general meeting of this society was held on Wednesday, the 21st inst., in the Rooms of the Royal Astronomical Society, Burlington House, W., Sir Napier Shaw, F.R.S., president, in the chair. The Report of the Council for 1919 was read and adopted, and the council for 1920 duly elected, the new president being Mr. R. H. Hooker, M.A. The Symons gold medal awarded to Professor H. H. Hildebrandsson, of the University, Upsala, was presented on his behalf to the Swedish Minister.

Sir Napier Shaw delivered an address on "*Pioneers in the Science of the Weather*," of which the following is an abstract:—

The year 1919 will be memorable in the annals of meteorology. It has witnessed the completion of the process of co-ordination of the national meteorological work in the operations of a single institution by the incorporation of the work of the British Rainfall Organisation with the Meteorological Office. Beginning with the meteorology of the sea alone in 1854, when it was a Department of the Board of Trade, in 1867, after FitzRoy's death, the office was charged with the mapping and the study of the daily sequence of weather, and on that account was placed in charge of a director with a "grant in aid" from Parliament under the control of a committee appointed by the Royal Society. In 1879, under a directive council, also appointed by the Royal Society, it became generally responsible for the publication of the national contribution of climatological data in accordance with an international scheme laid down by the Meteorological Congresses of Vienna in 1874, and Rome in 1879. In discharge of this duty it was authorised to obtain the aid of the Meteorological Societies, Royal and Scottish, and of the British Rainfall Organisation; it was also empowered to recognise the duty of development of meteorological science by experiments and special investigations.

From the early years of the twentieth century the collection of the climatological data of private observers became more and more associated with the office, until now, by the transfer of the British Rainfall Organisation the co-ordination is completed and the compilation of all information about weather is recognised as a common public duty centred in the Meteorological Office.

At the same time, in the course of the year, by decision of the War Cabinet on May 8, the Office itself has been "attached" to the Air Ministry; and, instead of deriving the public funds for its maintenance directly from Parliament through the Treasury, it will receive them through the Air Council, and the Air Ministers will be responsible to Parliament for them. What modifications of procedure are involved in the change are not yet known.

Since the year marks so important an epoch in meteorological history, the anniversary meeting of the society is an occasion on which we may commemorate those of our countrymen who have contributed to the organisation and development of meteorological science. Starting from the invention of the barometer by Torricelli in 1643 and proceeding in chronological order, we find examples of experimental investigation of the properties of air in the work of the Honourable Robert Boyle (1627), natural philosopher and philanthropist; of the design of meteorological instruments in Robert Hooke (1635), the first demonstrator of the Royal Society; of the compilation of observations at sea in the remarkable discourse on winds by William Dampier (1652), sailor and buccaneer; of meteorological theory in Edmund Halley (1656), natural philosopher and Astronomer Royal; in George Hadley (1685), a lawyer who explained the Trade Winds, and James Hutton (1726), a physician who developed a theory of rain.

Next came Richard Kirwan (1733), a weather-wise Irish gentleman, "consulted about the weather by half the farmers of Ireland," with ideas about the meteorology of the globe on the basis of the distribution of temperature Charles Wells (1757), physician of St. Thomas's Hospital, who elaborated the theory of dew; John Dalton (1766), famous for his atomic theory, teacher of mathematics and natural philosopher of Manchester, who put the theory of water-vapour in the atmosphere upon a physical basis, a lifelong meteorological observer and a student of the aurora, the height of which he measured successfully. Luke Howard (1772), a successful manufacturing chemist, an assiduous meteorologist, who classified clouds, introduced automatic records of the barometer, discoursed on the climate of London and studied the influence of the phases of the moon. Admiral Sir Francis Beaufort (1774), hydrographer of the Navy, who devised the Beaufort scale of wind-force and the Beaufort alphabetical notation for weather at sea. Edward Sabine (1788), Royal Engineer, secretary and later president of the Royal Society, and also general secretary of the British Association, who obtained the co-operation of those three great agencies in the magnetic survey of the British Isles, the trigonometrical survey of India, the establishment of magnetic observatories in Toronto, St. Helena, the Cape, India and elsewhere in the British Dominions, and of meteorological observations at all the foreign and Colonial stations of the Royal Engineers and Army Medical Department. He lived long enough to become the first chairman of committee of the Meteorological Office. John Frederic Daniell (1790), professor of chemistry, the inventor of the Daniell-cell and the Daniell dew-point hygrometer, a meteorological essayist and a writer on artificial climates for horticulture. And, finally, William Reid (1791), Major-General of the Royal Engineers, and Henry Piddington (1797), merchant seaman, author of the "Sailor's Horn Book," who made most notable contributions to the analysis of the phenomena of what the latter first called "cyclones," and are now in their many various forms the familiar elements of interest in the daily charts of weather prepared by meteorological offices all over the world. William Whewell (1795), the omniscient master of Trinity College, may perhaps be added as representing anemometry, thus carrying on the story of weather science as developed by those born before the end of the eighteenth century, and so bringing the history to the middle of the nineteenth, when the society was founded.

These names and histories show from what various sources meteorology has derived its ideas, its initiative and its support. In the future, as in the past, the science must preserve its wide outlook.

THE CAMMELLAIRD-FULLAGAR MARINE DIESEL OIL ENGINE.

OIL fuel as a source of power is greatly in the ascendant at the present time. Particularly is this the case with marine work, where its advantages have been fully realised as meeting exactly the peculiar conditions operating to-day. Of the ships building, a very considerable proportion are being designed and equipped for oil burning under boilers, and a number are in course of being refitted for oil burning instead of coal. In most cases arrangements are made so that reversion to coal at a later date can be quite readily and cheaply accomplished should altered circumstances warrant the laying up of the ship for the short period necessary.

In view of the extra fuel economy of oil engines as compared with the most economical double reduction geared turbine superheated steam oil-fired plant, effecting approximately the halving of the fuel bill for all purposes, the wider application of the internal combustion engine to marine work cannot longer be delayed, especially for those powers where the risks of unsatisfactory operation are reasonably low. Such, moreover, are the relative prices of coal and oil, that it is somewhat surprising that in Britain to-day so few oil engines are being installed in ships. Other maritime countries where tradition and conservatism are not such powerful forces as with us are most certainly going ahead in this direction more rapidly. It is to be regretted that records of performance, and available experience with marine oil engines in Britain at the present time, are such that the fitting of oil engines, no doubt duly considered, instead of coal and oil-fired steam plants, could not confidently be undertaken by shipowners to a much greater extent than is the case.

Some doubts are expressed in regard to the continued supply of suitable oil fuel at reasonable prices. With steam plants the reversion to coal-burning instead of oil can easily be accomplished, whereas the fitting of oil engines pledges the shipowners to oil fuel. This may act as a deterrent, but the main consideration concerns the prime mover itself. Apart from questions of reliability the disadvantages of the oil engine, increasing undoubtedly as the powers rise, may be said to be:—the large reciprocating masses involved, the complications of the valve gear and the general clumsy nature of the whole installation. With larger powers the saving in weight and space occupied as compared with the best steam practice is greatly reduced, whilst for all powers upwards from a limit between 300 s.h.p. and 500 s.h.p. the first cost of the Diesel engine is decidedly the higher. Unless there is a greater multiplicity of cylinders than with reciprocating steam practice, the shaft-twisting moment is relatively poor. As compared with the 4-stroke cycle the 2-stroke cycle engine, in theory and principle, should greatly minimise these disabilities. It cannot be said, however, that practice at sea has substantiated the oft-stated claims of the newer, the 2-stroke, cycle in these respects. Gains there undoubtedly are, but they have not been sufficiently marked to stem in any way the steady progress with the standard 4-cycle engine. Test-bed figures are not a sufficiently sure basis upon which to predict performance at sea.

Meantime, until an oil turbine arrives, a reciprocating mechanism is the only one to utilise the internal combustion principle. It is not unnatural, then, to seek for some rearrangement of the parts of the mechanism transmitting the power developed in the cylinders to the propeller, which will lessen some, if not all, of the disadvantages just mentioned.

With the steam engine many phases were passed through. The double-acting engine is now the standard and with oil engines will probably also be the final issue as regards reciprocating machinery. There are many difficulties, however, in the path of development towards this end. Is it not possible that some rearrangement of the mechanism can be regarded as a step in the direction of progress?

The opposed piston type of construction may be reconsidered. It has been tried for steam, gas and petrol engines, but has so far been found wanting. With steam the double-acting engine overcame all rival methods. With gas and petrol engines the two-cycle principle, due to scavenging and exhaust difficulties, has not gained much ground. The opposed piston engine has, so far, only been proposed for two-cycle work. It could, no doubt, be applied to the four-cycle principle, especially where the compression is low and the clearance volume large enough to admit of the accommodation conveniently of the inlet and exhaust valve. With the Oechelhauser gas engines as built, moreover, certain constructional features were of faulty design, and militated greatly against success.

As has been very frequently pointed out, the Diesel principle lends itself to the two-stroke cycle. The scavenging, exhaust and pre-ignition troubles experienced with two-cycle gas engines are absent with the Diesel oil engine. It is not, therefore, illogical to resuscitate this opposed piston principle and to consider it afresh in connection with its application to the Diesel oil engine provided substantial advantages would seem thereby to be possible of attainment.

The two-cycle opposed piston oil engine has the following attractive features:—There is no cylinder head, the liner is just a single tube free to expand at both ends. Scavenging can most efficiently be accomplished since the sweeping out air enters at the opposite end of the liner to that through which the exhaust passes. No valves are required to control the scavenging process. The piston speed can, in effect, be doubled due to the compression taking place between the two approaching pistons reducing the most important heat losses during this stroke of the cycle. The turning moment, due to the multiplicity of pistons connected to the crankshaft, is improved. Stresses are not taken up by the engine framing, but are confined to the moving parts of the engine. It can be shown that space and weight are saved. These advantages are substantially imposing and cannot be neglected. They are common to all opposed piston two-cycle engines.

It is, however, with one particular engine that the following description will deal. The Fullagar gas engine is fairly well known. Messrs. Cammell Laird and Co., of Birkenhead, have the exclusive rights to this principle as applied to marine oil engines, and are responsible for the development to be dealt with. Fig. 1, on the two-page Plate IX, explains the principle as applied to a four-crank engine with cranks arranged at 180 deg., while Figs. 2 and 3 on the same plate illustrate its development. By cross-connecting adjacent top and bottom pistons by oblique rods the number of cranks between adjacent bearings is reduced from three, with the usual opposed piston arrangement to two. This is an advantage, for, whilst the bending stresses in the crankshaft may, theoretically, be confined to between the points of application of the loads by the connecting rods E and F, any lack of shaft alignment will increase these stresses to an extent varying as the distance between the main bearing supports is greater or less. The connecting of the upper and lower adjacent pistons by oblique rods relieves the main engine framing of all stresses, except those imposed by the obliquity of the connecting rods. The loads so incurred are less than the normal tension loads and are comparable with the loads caused by obliquity of connecting rods. The manner in which the pistons uncover the ports at the top of the cylinder liner for the sweeping out of the exhaust and then for the introduction of the scavenging air at the bottom will be entirely clear. This form of construction diminishes the loads on the main bearings which, as already explained, are reduced in number compared with those usually fitted where each crank is supported at both sides. Each unit comprising two cylinders and four pistons, is equal in effect to a single cylinder double-acting steam or oil engine, and with this Fullagar construction, the same effect is obtained with two connecting rods, two cranks, two cylinders and four pistons as would require two cylinders, four pistons, six connecting rods, and six cranks with the ordinary opposed piston type of engine.

The manner in which the framing of the engine is used as a reservoir for the scavenging air delivered from the scavenging pumps driven from the top pistons will be clearly seen from the sections, Figs. 2 and 3, on Plate IX.

In Fig. 4 is given a comparison of the turning moment diagrams of two engines showing the advantages of the Fullagar system in this respect. With small internal combustion engines the evenness of turning moment is rather more of a "talking" point than of substantial advantage. It is rather remarkable that it should be so. The difference in the running of a six-cylinder two-cycle as compared with a six-cylinder

Fig. 4. 12 CYL. CAMELLAIRD FULLAGAR HEAVY OIL ENGINE. *12 CYL. EXISTING FOUR CYCLE ENGINE.*

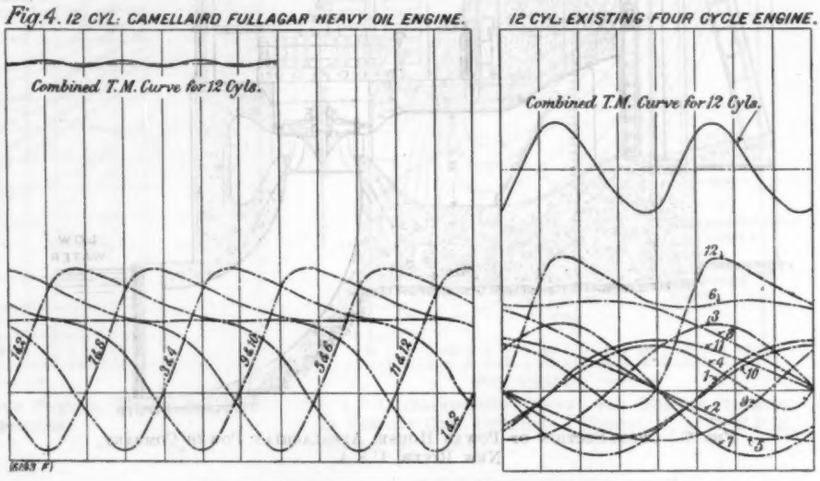


FIG. 4. COMPARATIVE TURNING MOMENT CURVES.

Fig. 5.

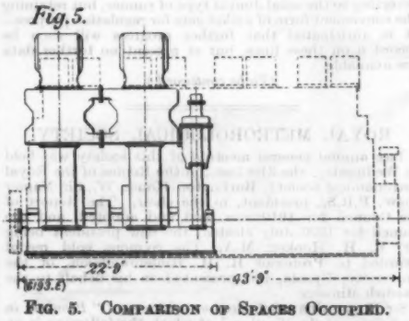


FIG. 5. COMPARISON OF SPACES OCCUPIED.

four-cycle in actual practice is really very slight, although a bigger flywheel requires to be fitted in the case of the four-cycle than would be required by a two-cycle to achieve a given cyclic regularity in operation. The large flywheel, of course, imposes certain disadvantages. The diagrams (Fig. 4) compare a 12-cylinder Cammellaird-Fullagar engine with a similar four-cycle existing engine, and show the remarkably even turning moment that would be achieved by a 12-cylinder Cammellaird engine. The opposed piston principle makes possible the reducing of the diameter of the shaft since the load from any explosion is distributed over the two adjacent cranks and the bending moment is, to some extent, confined between the centres of the two closely-pitched adjacent connecting rods.

In regard to space occupied, Fig. 5 shows an existing 1,550 i.h.p. four-cycle marine engine and a Cammell-aird-Fullagar engine of the same power. Fig. 6, on page 145, is also given by the makers in this connection as showing a comparison of the fore and aft room taken up by three types of construction. Firstly (*a*) two pistons of an ordinary two-cycle single-acting engine, where the bearing centres are determined principally by considerations of crankshaft scantlings; (*b*) two pistons of the usual opposed piston type of engine; (*c*) four pistons of the new engine. The relative spaces occupied by these three methods of construction are shown in the diagrams from which it will be seen that the average opposed piston engine effects a slight saving over the normal construction, and with the Fullagar construction there is a very distinct saving due to the considerable greater power capable of development by the Fullagar engine with its four pistons. This comparison, it is claimed, assumes equal mean effective pressures and piston speeds.

With all two-cycle engines scavenging must be provided for. The most efficient method of scavenging is undoubtedly that of the four-stroke cycle where two complete strokes are given over to clearing the cylinder of exhaust gases and refilling with fresh air for a new cycle. Scavenging in such case is carried out only at the cost of friction losses of two whole working strokes of the main engine and the power so lost must be compared with that absorbed in compressing the scavenging air of the two-cycle system. In all but the largest engines, it is the standard practice to drive the scavenging pumps

THE CAMMELLAIRD-FULLAGAR MARINE OIL ENGINE.

CONSTRUCTED BY MESSRS. CAMMELL LAIRD AND CO., LIMITED, ENGINEERS, BIRKENHEAD.

Fig. 6.

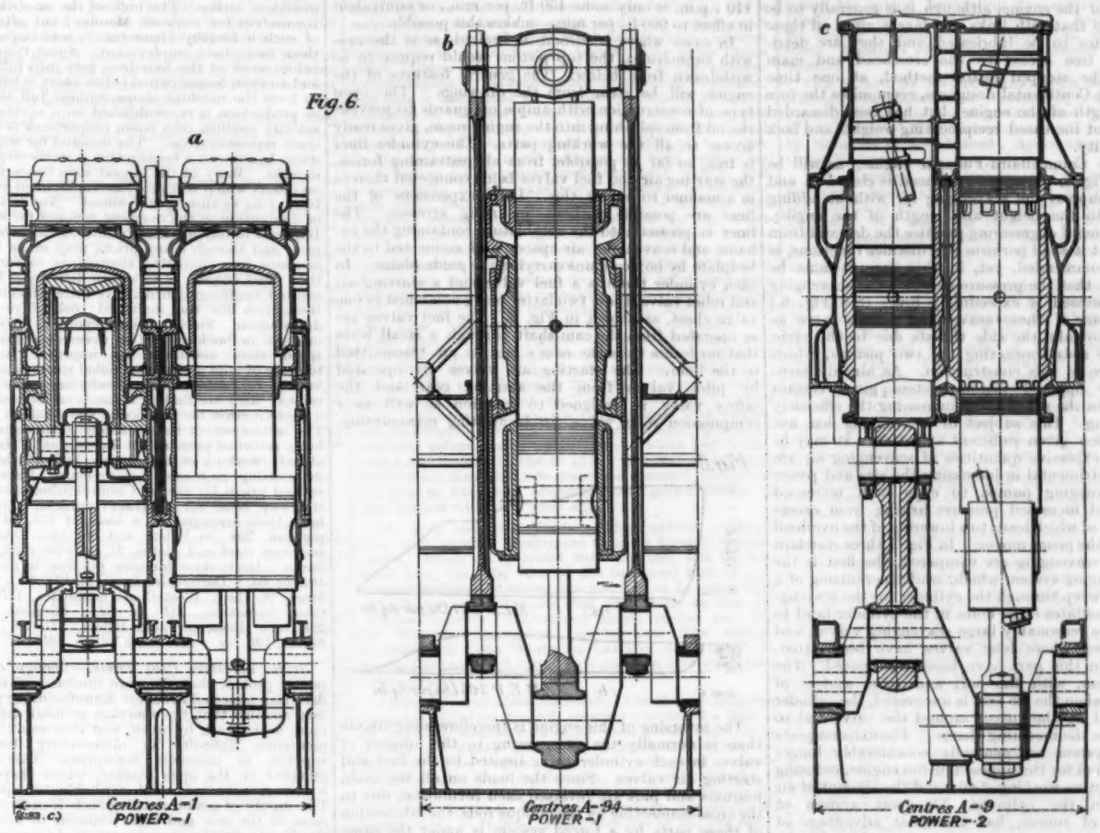


FIG. 6. COMPARISON OF FORE AND AFT LENGTH OF THREE TYPES OF ENGINES.

Fig. 7.

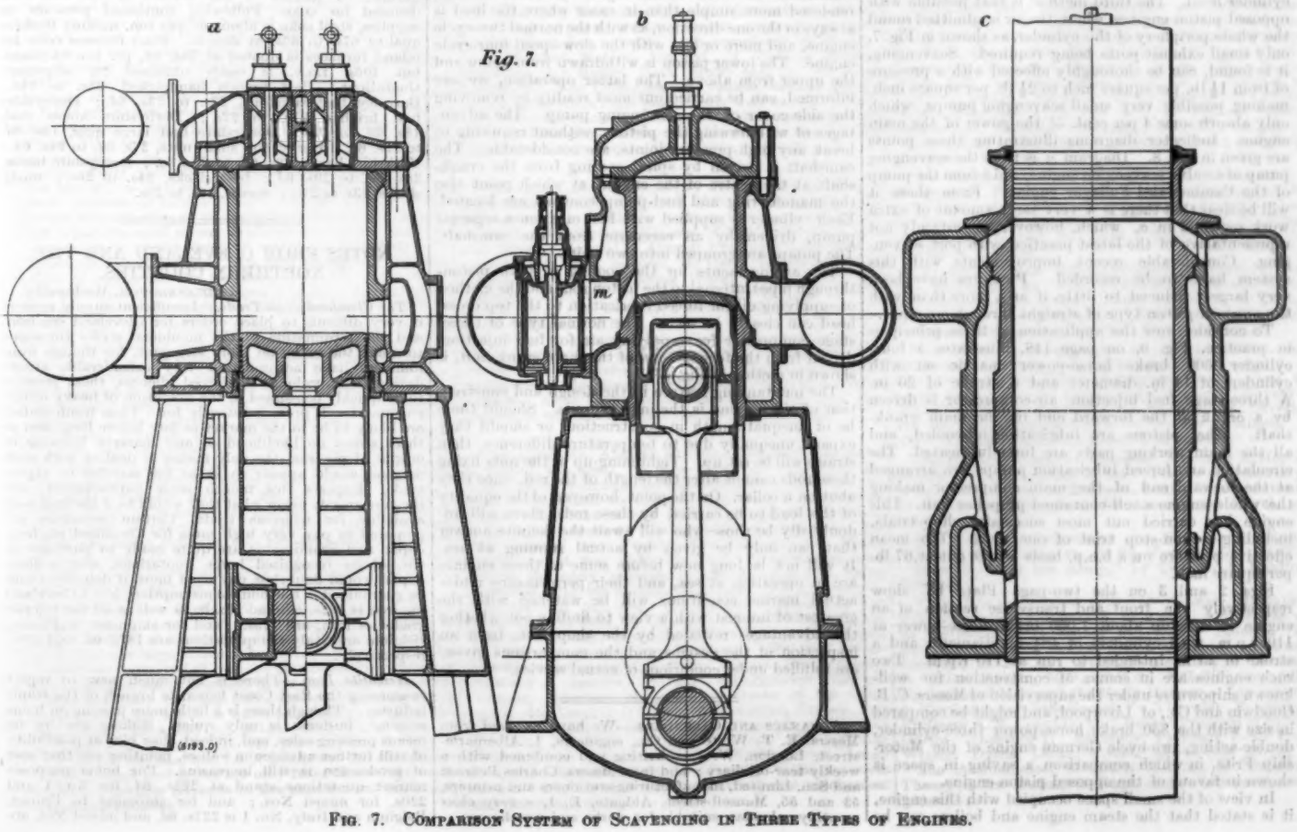


FIG. 7. COMPARISON SYSTEM OF SCAVENGING IN THREE TYPES OF ENGINES.

direct from the main engine. There are various methods in vogue such as a drive by links and levers from the main crossheads or by a separate crank on the forward end of the crankshaft. This latter method increases the length of the engine, although it is generally to be preferred to that with links and levers, since all these joints require to be lubricated and they are detrimental to free access to the crosshead and main pistons. The stepped piston method, at one time favoured by Continental designers, economises the fore and aft length of the engine, but has been discarded for reasons of increased reciprocating weights and lack of accessibility.

With the Cammellaird-Fullagar engine, as will be seen from Fig. 1, the upper crosshead is closed in and used to compress the scavenging air without adding materially to the height and length of the engine. Whilst in general engineering practice the demand from one part that it shall perform two distinct functions, is not to be commended, yet, in this case, it must be pointed out that the pressure to which the scavenging air is compressed is exceedingly low. (See Fig. 8.)

The pistons of these scavenging pumps serve as crossheads to take the side thrusts due to the main oblique side rods connecting the two pistons, which are a feature of this construction. As already mentioned, the opposed piston system gives certain advantages in the direction of increasing the efficiency of scavenging. This subject of scavenging has not generally been given sufficient attention. It may be stated that excessive quantities of scavenging air are distinctly detrimental in increasing the size and power of the scavenging pumps to cope with increased quantity and increased pressure arising from excess quantity, all of which leads to a lowering of the overhaul efficiency of the prime mover. In Fig. 7, three standard methods of scavenging are compared, the first is the valve scavenging system which, whilst permitting of a fairly good sweep through the cylinder for the scavenging air, necessitates large holes in the cylinder head to accommodate reasonably large scavenging valves, and in some cases where four valves have been fitted, weaknesses in this part have been experienced. The second system, with the port and valve system of scavenging, when the air port is uncovered, the cylinder gases will fill up the spaces around the valve and so tend to dilute the incoming charge. The exhaust ports with this system are generally considerably longer than is required for the opposed piston engine, reducing thus the effective working stroke and the amount of air remaining in the cylinder. The port system of scavenging, of course, has the great advantage of eliminating the large scavenging air valves in the cylinder head. The third method is that possible with opposed piston engines, where the air is admitted round the whole periphery of the cylinder, as shown in Fig. 7, only small exhaust ports being required. Scavenging, it is found, can be thoroughly effected with a pressure of from 1½ lb. per square inch to 2½ lb. per square inch, making possible very small scavenging pumps, which only absorb some 4 per cent. of the power of the main engine. Indicator diagrams illustrating these points are given in Fig. 8. Diagram *a* is from the scavenging pump of a valve scavenging engine, and *b* from the pump of the Cammellaird-Fullagar engine. From these it will be clear that there is a very large amount of extra work required in *a*, which, however, is certainly not representative of the latest practice with port scavenging. Considerable recent improvements with this system have to be recorded. Pressures have been very largely reduced to little, if any, more than with the opposed piston type of straight through scavenge.

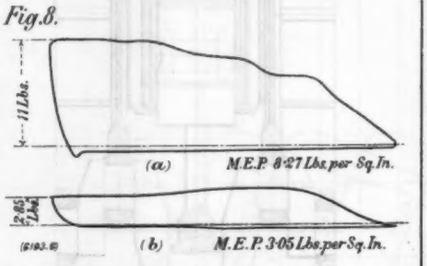
To consider now the application of these principles in practice, Fig. 9, on page 148, illustrates a four-cylinder 500 brake horse-power marine set with cylinders of 14 in. diameter and a stroke of 20 in. A three-stage fuel injection air-compressor is driven by a crank at the forward end of the main crankshaft. The pistons are lubricating oil-cooled, and all the main working parts are force-lubricated. The circulation and forced lubrication pumps are arranged at the forward end of the main compressor making the whole engine a self-contained propeller unit. This engine has carried out most successful shop trials, including a non-stop trial of one week. The mean effective pressure on a b.h.p. basis works out at 67 lb. per square inch.

Figs. 2 and 3 on the two-page Plate IX show respectively the front and transverse section of an engine to develop about 1,000 brake horse-power at 110 r.p.m. with cylinders of 18½ in. diameter and a stroke of 25 in. intended to run at 110 r.p.m. Two such engines are in course of construction for well-known shipowners under the supervision of Messrs. C. B. Goodwin and Co., of Liverpool, and might be compared in size with the 850 brake horse-power three-cylinder, double-acting, two-cycle German engine of the Motorship Fritz, in which comparison a saving in space is shown in favour of the opposed piston engine.

In view of the small space occupied with this engine, it is stated that the steam engine and boilers can be taken out of existing steamships and replaced by an engine of this type without altering the shafting or propellers. The low speed of revolution consequent upon the adoption of opposed pistons—the piston-speed at 110 r.p.m. is only some 450 ft. per min., or equivalent in effect to 900 ft. per min.—makes this possible.

In cases where headroom is limited, as is the case with submarines, the top pistons would require to be withdrawn from below. The general features of the engine will be clear from the drawings. The open type of construction with ample oil guards to prevent the oil from splashing into the engine room, gives ready access to all the working parts. The cylinder liner is free, so far as possible, from all restraining forces, the starting air and fuel valves being connected thereto in a manner to permit this. Large expansions of the liner are possible without incurring stresses. The liner is pressed into the entablature containing the exhaust and scavenging air spaces and connected to the bedplate by box columns carrying the guide-plates. In each cylinder there is a fuel valve and a starting air and relief valve, these two latter being combined in one valve chest, as shown in Fig. 3. The fuel valves are so operated from the cam-shaft through a small lever that no forces from the cam's motion are transmitted to the liner. The starting air valves are operated by pilot valves from the starting gear and the safety valve is designed to function as well as a compression relief valve for facilitating manœuvring.

Fig. 8.



The reversing of this engine is therefore more simple than is normally the case, owing to the number of valves in each cylinder being limited to the fuel and starting air valves. Since the loads on all the main journals and pins are reversed each revolution, due to the cross-connecting by the oblique rods, the lubrication of these parts by a forced system is under the same conditions as with steam-engine practice, and is rendered more simple than in cases where the load is always in the one direction, as with the normal two-cycle engine, and more or less with the slow-speed four-cycle engine. The lower piston is withdrawn from below and the upper from above. The latter operation, we are informed, can be carried out most readily by removing the side cover of the scavenging pump. The advantages of withdrawing the pistons, without requiring to break any high-pressure joints, are considerable. The camshaft is driven by spiral gearing from the crankshaft at the centre of the engine, at which point also the manœuvring and fuel-pump controls are located. Each cylinder is supplied with fuel oil from a separate pump, driven by an eccentric from the camshaft. The pumps are grouped into two units.

The arrangements for the cooling of both pistons through pipes internal to the piston rods and the method of supplying oil for forced lubrication to the top crosshead can clearly be seen. The normal type of three-stage compressor for supplying air for fuel injection, driven from the forward end of the main crankshaft, is shown in section in Fig. 2.

The outstanding feature in the design and construction of this engine is the inclined rods. Should these be of unequal length in construction, or should they expand unequally due to temperature difference, then strains will be set up. Tightening-up of the nuts fixing these rods cannot alter the length of the rod, since they abut on a collar. On the point, however, of the equality of the load to be carried by these rods, there will undoubtedly be those who will await the definite answer that can only be given by actual running at sea. It will not be long now before some of these engines are in operation at sea, and their performance under actual marine conditions will be watched with the greatest of interest with a view to finding out whether the advantages revealed by the shop test, from an inspection of the designs and the comparisons given, are fulfilled under conditions of actual service.

ALMANACS AND CALENDARS.—We have received from Messrs. E. T. White and Co., engineers, 1, Albemarle-street, London, W. 1, a writing pad combined with a weekly tear-off diary; and from Messrs. Charles Pearson and Son, Limited, manufacturing stationers and printers, 53 and 55, Mansell-street, Aldgate, E. 1, a very clear monthly calendar, suitable for works and warehouses.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The outlook in the engineering trade has brightened considerably with the settlement of the moulders' strike. The bulk of the ex-strikers presented themselves for work on Monday, but after a set-down of such a lengthy character, it was impossible to find them immediate employment. Some time must elapse before work at the foundries gets into full swing again, and an even longer period before there is sufficient output to keep the machine shops running full time. As soon as production is re-established on a normal basis, great activity swelling into boom proportions is forecasted by trade representatives. The demand for engineering products has shown a tremendous increase over the last six months. Many of the largest steel concerns have taken on orders which will provide employment for six months to as long as three years ahead. Nor is there any sign of diminution in the overseas demand for local material. Inquiries to-day are more numerous than for a long time past, and though rising prices may make buyers rather cautious in committing themselves to future business, their chief anxiety is to secure delivery. If this can be assured, engineering firms have little difficulty in covering themselves for the increased cost of production and distribution. Steel makers report a very satisfactory increase in bookings. The overseas demand for high-speed steel continues to improve. A tremendous tonnage of mild and special rolled steel is going to France, largely for automobile manufacture, while makers of railway steel are finding a much easier task in securing a ready market for practically the whole of their output. The settlement of the moulders' dispute is expected to bring returned pressure on file output. The file trade is already working at high speed, and will have difficulty in meeting increased requirements. Definite fixing of revised prices for raw and semi-finished materials leaves the way clear for contract business. The new rates have been arranged on a basis of 17*s.* 6*d.* advance on pig-iron, 30*s.* on billets and bar iron, 25*s.* to 40*s.* on sectional steel and plates, 3*l.* on wire rods, and 40*s.* on hoops. Derbyshire foundry pig-iron is now quoted at 10*l.* 2*s.* 6*d.*; Derbyshire forge, 9*l.* 12*s.* 6*d.*; Lincolnshire forge, 9*l.* 15*s.*; West Coast hematites, 11*l.* 15*s.*; East Coast hematites, 11*l.* 7*s.* 6*d.*; Siemens acid billets, 22*l.* 5*s.*; Bessemer acid billets, 21*l.* 5*s.*; hard basic billets, 19*l.* 10*s.*; soft basic billets, 19*l.*

South Yorkshire Coal Trade.—Though colliery companies protest that they are innocent of the charge of diverting household fuel for manufacturing purposes, the fact remains that the shortage at local depots becomes more acute week by week, and that small dealers have increasing difficulty in maintaining hand-to-mouth supplies to domestic consumers. This scarcity is reflected on the open market, where there is scarcely a ton of household fuel available for spot purchase. The supply of manufacturing fuels is sufficient to enable most of the iron and steel concerns to increase stocks. Conditions in the steam coal trade are again almost normal. A feature of the market is the enormous demand for coke. Following continued pressure on supplies, steel coke is about 6*s.* per ton, making Beehive quality 67*s.* to 65*s.* at depots. Blast-furnace coke for inland furnaces is quoted at 53*s.* 6*d.* per ton at ovens, but 105*s.* f.o.b. is easily obtained for shipment. Quotations:—Best branch handpicked, 23*s.* to 24*s.*; Barnsley best silkstone, 23*s.* to 23*s.* 6*d.*; Derbyshire best brights, 21*s.* to 22*s.*; Derbyshire house coal, 18*s.* 6*d.* to 19*s.*; Derbyshire best large nuts, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire small nuts, 27*s.* 6*d.* to 28*s.* 6*d.*; Yorkshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; Derbyshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; best slacks, 24*s.* to 25*s.*; nutty slacks, 23*s.* to 24*s.*; smalls, 19*s.* to 20*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Insufficient supply renders it very difficult to place orders for Cleveland pig-iron, and the termination of the moulders' strike threatens to make the situation more stringent, for though iron-founders have accumulated very considerable stocks during their prolonged enforced idleness, these promise to be quickly consumed in the execution of heavy orders customers will press insistently for. Thus ironfounders are likely to be in the market to buy before long, and as there seems no likelihood of any material increase of output of pig-iron, the only means of dealing with such demand would appear to be at the sacrifice of export trade. Exports this month show improvement, but they are greatly below what they would be if the iron were available for overseas trade. Certain countries are prepared to pay very high rates for Cleveland pig-iron. Japan and Scandinavia are quite ready to purchase at 45*s.* above recognised home quotations, and, indeed, Japan would doubtless pay even more if delivery could be guaranteed. For home consumption, No. 1 Cleveland pig-iron is 182*s.* 6*d.* and No. 3, as well as all the inferior grades of iron, are 175*s.*; and for shipment to France, Belgium and Italy the quotations are 187*s.* 6*d.* and 180*s.* respectively.

Hematite Iron.—There is not much new to report concerning the East Coast hematite branch of the staple industry. Though there is a little more passing on home account, business is only quiet. Makers are by no means pressing sales, and, indeed, they hint at possibility of still further advance in values, pointing out that cost of production is still increasing. For home purposes market quotations stand at 222*s.* 6*d.* for No. 1 and 220*s.* for mixed Nos.; and for shipment to France, Belgium and Italy, No. 1 is 227*s.* 6*d.* and mixed Nos. are

225*s*. For export to other countries the minimum rate named for hematite is 230*s*.

Foreign Ore.—Sellers of ore take a very firm stand, and continue to ask prices consumers consider prohibitive. Market rates are now based on 48*s*. for rubio, of 50 per cent. quality, on a parity freight of 17*s*., Bilbao-Middlesbrough, and as the freight is now 31*s*., the c.i.f. Tees price of best rubio may be put at 62*s*.

Coke.—Coke is very scarce, so much so that one blast furnace or two have had to be dropped on to slack blast. Average furnace quality is 50*s*. 3*d*. at the ovens, and low phosphorus kind is 53*s*. at the ovens.

Manufactured Iron and Steel.—So overwhelmed with work are manufacturers of finished iron and steel that many of them have closed their books with a view to clearing off some arrears before they entertain new business. Customers are pressing heavily for deliveries under contracts made. Export quotations are matters of negotiation, but are above the following, which are among the principal market rates for home use: Common iron bars, 24*l*.; marked bars, 27*l*.; small steel bars, 22*l*.; steel strip, 27*l*. 10*s*.; steel hoops, 27*l*. 10*s*.; steel ship, bridge and tank plates, 20*l*.; steel angles, 19*l*. 10*s*.; steel boiler plates, 23*l*.; steel joists, 19*l*. 10*s*.; heavy sections of steel rails, 18*l*. 15*s*.; fishplates and sleepers, 23*l*. 15*s*.; and galvanised sheets, 47*l*.

Wagon Shortage and the Steel Trade. Stocks of finished steel are accumulating rapidly as the result of manufacturers being unable to make anything like full deliveries due to the scarcity of suitable wagons, and so congested are some works that output is having to be restricted. Steel producers are this week making representations to the authorities with a view to obtaining more trucks. They feel that the North-East Coast has been unfairly treated in the matter of wagon supply.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—The eagerness to secure supplies of steel material which has characterised the Scotch steel trade for some months back is as great as ever, and the past week has been no exception to its predecessors. The keenness for deliveries would, in fact, seem to be getting greater, and consumers keep pressing for supplies with the result that the different establishments are being kept fully employed. From one or two sources we hear of the workers doing their best to increase the output, which is very encouraging, and if that were only general the country as a whole would benefit to a considerable extent. For ship plates there is a great outlet, but in the meantime the present supply is barely equal to the needs of the home yards, and some of the Clyde shipbuilders cannot get forging ahead on account of the shortage. That is an unfortunate position on account of the great need for new tonnage. Inquiries for export lots are good, and a large business could be done were makers able to offer, but with the home requirements so pressing little attention can be given to export lines. The demand for black sheets continues large, and there is an ever-pressing request for deliveries both on home and export account, and in the latter connection quite a fair business is passing in the heavier gauges. There is no lack of new orders but at present order books are well filled up for the more immediate future. Sections are once more the subject of a better inquiry, and during the past week or two there has been a fairly good turnover, with makers well able to meet the demand. Steel joists are finding a ready sale round 21*l*. per ton for local delivery and 2*l*. higher for export lots. The shipping side of the steel industry moves slowly and the weekly tonnage exported does not amount to anything very considerable, which is in great contrast to former times. A good business could be put through even at higher prices than are mentioned, but when the stuff is not available any figure could be named, as it is the delivery which counts nowadays. Prices all round continue firm and instead of showing signs of easing off the tendency is all the other way. The present activity in the trade is likely to last for quite a long time owing to the world's shortage of material.

Malleable Iron Trade.—Everything possible in the way of speeding-up output is being done by the malleable iron makers in the West of Scotland, but the demand is quite extraordinary and deliveries are entering into consumption as quickly as they come to hand. Bookings are already very heavy, and still many very tempting inquiries keep arriving. These amount to a very respectable tonnage, but nothing in the way of fresh business can be looked at for a long time ahead, and even then only at the price ruling at the time of delivery. Stocks on hand are now a thing of the past and consumers are kept working on the hand-to-mouth principle. Prices which have been very strong for some time have again been advanced, and "crown" bars are now called for home delivery 24*l*. per ton, net, at station Glasgow, and 24*l*. 10*s*. per ton, net, f.o.b. Glasgow, for export. The export business is small on account of the very large demand for local consumption.

Scotch Pig-Iron Trade.—A good tone prevails in the Scotch pig-iron trade and most of the present output is being used up at home, the demand being very strong. Owing to the large tonnage being required locally there is no great quantity left over for exporting, but whatever is available is easily disposed of for the overseas market. There are many inquiries going around at present, and business on the whole is quite satisfactory despite the high figure demanded by sellers. For No. 1 foundry iron the price is called 11*l*. 15*s*. per ton, and for No. 3 it is 5*s*. per ton less, net, f.o.b. Glasgow. All quotations are very firm, and prices are only from day to day, and, in fact, a further advance in the near future would not come as a surprise.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Coal Market.—Very little business is possible as shipping already in dock is ample to meet the requirements of collieries and more than can be conveniently dealt with by the inadequate loading facilities. As a consequence, detention is acute, and in numerous cases vessels have been waiting as much as a fortnight without being able to secure loading berths. The order under which railway companies were allowed to use colliery-owned wagons on returned journeys has been suspended, and this is calculated to increase the supply of trucks available in the coal trade, as it will now be possible to return wagons empty and thus save much delay, and thereby expedite the transport of coal from pit to docks. In the majority of cases collieries are fully booked up with orders for shipment well into next month, and consequently buyers experience difficulty in securing even small parcels of all grades, and for the odd lots available sellers can readily secure 110*s*. for the better quality large coals and up to 95*s*. for best steam smalls. In some instances 115*s*. is asked for best large, but the general market price is round 110*s*. Foreign shipments of coal last week amounted to 409,093 tons, compared with 461,658 tons in the preceding week. Of the former total 211,333 tons was despatched from Cardiff, 101,739 tons from Newport, 68,629 tons from Swansea and 27,392 tons from Port Talbot. As usual more than half the total shipments went to France, namely, 213,256 tons, Italy 47,392 tons, South America 54,189 tons, Spain 13,116 tons, Portugal 32,206 tons, British coaling depots 36,288 tons and to "other countries" 12,646 tons. Coke-makers, too, are fully booked with orders, and free supplies are scarce, and for the small quantities available sellers realise up to 130*s*. Patent fuel is also scarce and firmer at 110*s*. to 115*s*. Arrivals of imported pitwood are insufficient to meet the demand, and prices are firm at 85*s*., with allocated home-grown timber at 73*s*., against 67*s*. 6*d*. a week ago.

The Iron and Steel Trades.—This market continues firm, with supplies inadequate to meet buyers' requirements. Block tin is round 388*l*. per ton, and tin and sheet bars, 25*l*. In view of the increased cost of production makers are asking 7*l*. per ton, or 5*s*. more than a week ago, and business has been done at 68*s*. for October delivery. Galvanised sheets realise 48*l*. 10*s*. for 24-gauge corrugated, in bundles. The British Mannesmann Tube Works at Landore have been idle during the past week owing to a question involving trade union rivalry.

Value of Second-Hand Steamers.—The Monroe Shipping Company, Limited, Cardiff, recently purchased a fleet of 10 coasting steamers of 3,300 tons deadweight from Messrs. J. Monks and Co., Limited, Liverpool, for 200,000*l*. The buyers have also sold their steamer Francia, 1,640 tons deadweight, which they bought in May last for 61,000*l*., to the Cardiff Steam Navigation Company, Limited, for 85,000*l*., which represents an appreciation of 24,000*l*. in eight months or 39½ per cent.

MOBILE ARC-WELDING SET.—An interesting vehicle, comprising a petrol-electric chassis carrying an arc-welding plant has recently been completed by Messrs. Tilling-Stevens Motors, Limited, of Victoria Works, Maidstone, for Messrs. P. A. Mudd and Co., of West Hartlepool. The Tilling-Stevens vehicle, with its petrol-electric drive lends itself particularly well to work of this kind, since the electric generator, which is normally used for propelling the vehicle, can be used to supply the current for welding when the vehicle is at rest.

UNIVERSITY OF BIRMINGHAM; SPECIAL ENGINEERING LECTURES.—Sir Henry Fowler, K.B.E., chief mechanical engineer of the Midland Railway Company, and late Director of Production, Ministry of Munitions, and Assistant Director-General of Aircraft Production, will deliver a course of three lectures on the "Organisation and Management of Engineering Works," as follows: (1) Tuesday, February 10, (chairman, Sir Herbert Austin, K.B.E., M.P.; (2) Monday, February 16, (chairman, Mr. J. D. Siddeley, C.B.E., of Coventry); (3) Tuesday, February 24, (chairman, Mr. Neville Chamberlain, M.P.) The lectures will be given in the Medical Theatre, The University, Edmund-street, commencing at 5.45 p.m. Engineers of the district are cordially invited to these lectures. After each lecture there will be a brief discussion, in which it is hoped visitors will take part.

THE LATE MR. ALBERT SCHMID.—We regret to have to record the death, in New York, on December 31, of Mr. Albert Schmid, who was closely identified with the early development of electrical machinery in the United States. Mr. Schmid was born in Zurich, Switzerland, in 1857, and received his education in that city. He then entered the French Westinghouse Air Brake Company; it was there that Mr. Westinghouse met him in the early 'eighties of last century and, being impressed with his ability, he invited him to America. After carrying out work for Mr. Westinghouse, he was transferred, in 1886, to the newly-created Westinghouse Electric Company, becoming its first chief engineer and, in 1896, its general superintendent. He was subsequently director-general of the French Westinghouse Company; director of the Westinghouse Electric Company, Limited, England; president of the Compagnie des Lampes à Filament-Metallique, France. At the time of his death, in addition to his position as consulting engineer to the American Westinghouse Company, he represented the Westinghouse Lamp Company and had general supervision of its interests abroad. Mr. Schmid was a most capable mechanical and electrical engineer.

NOTICES OF MEETINGS.

THE INSTITUTION OF CIVIL ENGINEERS.—STUDENTS' MEETING.—Friday, January 30, at 6 p.m., Second Vernon-Harcourt Lecture on "The Economic Requirements for Inland Navigation Transport in the British Isles," by Mr. R. B. Dunwoody, Assoc.M.Inst.C.E. Mr. Sidney Preston, C.I.E., M.Inst.C.E., will occupy the chair. Members of all classes are invited to attend the lecture.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.—Saturday, January 31, at 2 p.m., Meeting of the Associates and Students in the Wood Memorial Hall, Newcastle-upon-Tyne. Addresses by Members of the Council; Appointment of Officers; Other Business.

THE SOCIETY OF CHEMICAL INDUSTRY.—LONDON SECTION.—Monday, February 2, at 8 p.m., Meeting at the Rooms of the Chemical Society, Burlington House, Piccadilly, W., when the following paper will be read: 'The Theory and Practice of Lubrication: The Germ Process," by Mr. Henry M. Wells and Mr. James E. Southcombe, M.Sc.

THE ROYAL SOCIETY OF ARTS.—Monday, February 2, at 8 p.m.: Cantor Lecture, "Aircraft Photography in War and Peace," by Captain H. Hamshaw Thomas, M.B.E., M.A., F.G.S., Fellow of Downing College Cambridge, and formerly of the Royal Air Force (Lecture III). Tuesday, February 3, at 4.30 p.m.: Colonial Section, "Tropical Departments of Agriculture, with Special Reference to the West Indies," by Sir Francis Watts, K.C.M.G., D.Sc., Imperial Commissioner of Agriculture for the West Indies. Lieutenant-Colonel Sir David Prain, C.M.G., C.I.E., LL.D., F.R.S., Director of the Royal Botanic Gardens, Kew, will preside. Wednesday, February 4, at 4.30 p.m.: Ordinary Meeting, "The English Language and International Trade," by Mr. Alfred E. Hayes, General Secretary, English Language Union. Sir Edward Brabrook, C.B., F.S.A., will preside.

THE LIVERPOOL ENGINEERING SOCIETY.—Wednesday, February 4, at 8 p.m., Meeting at the Royal Institution, Colquitt-street, Liverpool, when a paper will be read by Mr. A. T. Wall, Grad.R.N.C.(Greenwich), A.R.C.Sc. M.Inst.N.A., entitled "Reversing and Manœuvring Rudders," illustrated by lantern slides, cinematograph and working models.

THE INSTITUTE OF COSTS AND WORKS ACCOUNTANTS, LIMITED.—Wednesday, February 4, at 7 p.m., at the Hall of the Institute of Chartered Patent Agents, Staple Inn Buildings, Holborn, a Lecture will be given on "The Principles and Practice of Correct Costing." Chairman, Sir Robert Hadfield, Bart., D.Sc., F.R.S.; Lecturer, Mr. A. E. Goodwin, F.C.W.A.

THE ROYAL AERONAUTICAL SOCIETY.—Wednesday, February 4, at 8 p.m., at the Royal Society of Arts, John-street, Adelphi, London, W.C. 2. A paper on "Rigid Airships and Their Development" will be read by Squadron Leader J. E. M. Pritchard, O.B.E., R.A.F. The chair will be taken by Air-Commodore E. M. Maitland, C.M.G., D.S.O., R.A.F.

THE ASSOCIATION OF ENGINEERING AND SHIPBUILDING DRAUGHTSMEN.—Wednesday, February 4, at 7.30 p.m., at the Liverpool University Engineering Lecture Theatre, Mr. W. A. Barnes, Wh. Ex., A.M.I.Elec.E., on "Electric Traction." Thursday, February 5, at 7.30 p.m., at Milton Hall, Deansgate, Manchester, Mr. M. Coronel, on "Gearing Design," being an official Association Lecture. Friday, February 6, at 7.30 p.m., at Applied Science Department, Sheffield University, Mr. J. Davison, on "Lubrication of High-Speed Bearings," being an official Association Lecture.

THE INSTITUTION OF AUTOMOBILE ENGINEERS.—Wednesday, February 4, at 8 p.m., Meeting in the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W. 1. Mr. A. P. Young and Mr. H. Warren will read a paper entitled "The Process of Ignition."

THE BIRMINGHAM METALLURGICAL SOCIETY.—Thursday, February 5, at 7 p.m., at the Birmingham Chamber of Commerce, New-street. Paper by Mr. F. C. Thompson, D.Met., B.Sc.(Sheffield), "The Extension of Heat Treatment Processes to the Non-Ferrous Alloys."

THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.—Thursday, February 5, at 2.15 p.m., at the Hotel Metropole, Leeds, when the papers on "Notes on the Introduction and Delivery of Coke-Oven Gas to Sheffield," by Mr. J. H. W. Laverick, and on 'Applications of Ferro-Concrete in Mines," by Mr. J. T. Guéritte, will be open for discussion.

THE ROYAL SOCIETY.—Thursday, February 5, Meeting at 4.30 p.m. Discussion on the "Theory of Relativity," to be opened by Mr. J. H. Jeans, Sec.R.S., and continued by Professor Eddington, the Astronomer Royal, and others.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, February 6, at 7.30 p.m., at 39, Victoria-street, S.W. 1. "Tank Work in the Army," by Captain J. Bradford, Member.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday evening, February 6, at 9 p.m., a discourse will be delivered by Professor Sir Walter Raleigh. The subject is "Landor and the Classic Manner." Afternoon Lectures, at 3 p.m.: Tuesday, February 3, Professor G. Elliot Smith, M.D., F.R.S., F.R.C.P., on "The Evolution of Man and the Early History of Civilisation: 2. Elephants and Ethnologists"; Thursday, February 5, Professor A. E. Conrady, on "Recent Progress in Applied Optics" (Lecture I); Saturday, February 7, Sir Frank Watson Dyson, LL.D., F.R.S., Astronomer Royal, on "The Astronomical Evidence Bearing on Einsteins' Theory of Gravitation: 2. Displacement of Solar Spectral Lines."

THE CAMMELLAIRD-FULLAGAR MARINE OIL ENGINE.

CONSTRUCTED BY MESSRS. CAMMELL LAIRD AND CO., LIMITED, ENGINEERS, BIRKENHEAD.

(*For Description, see Page* 144.)

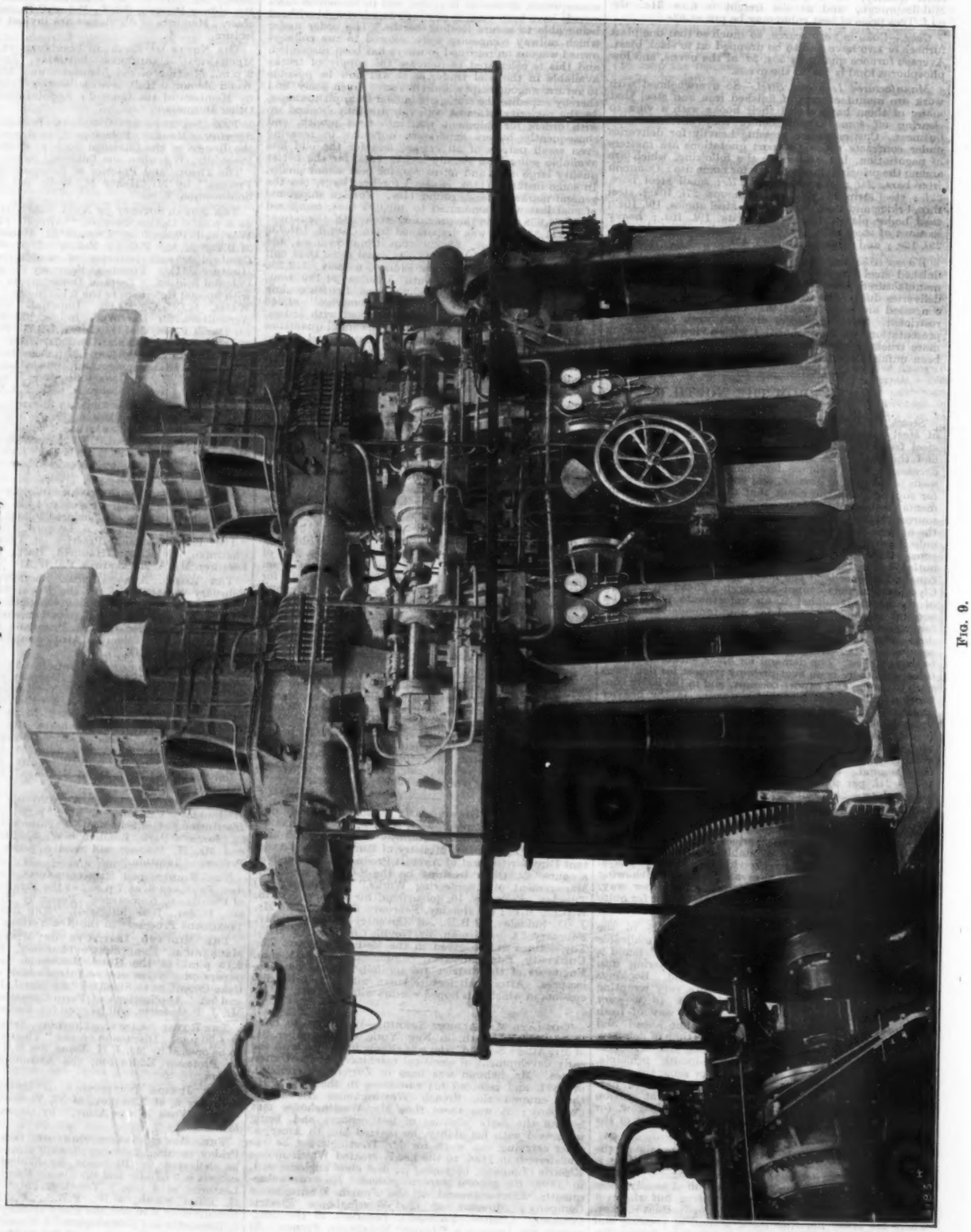


FIG. 9.

THE CAMMELLAIRD-FULLAGAR

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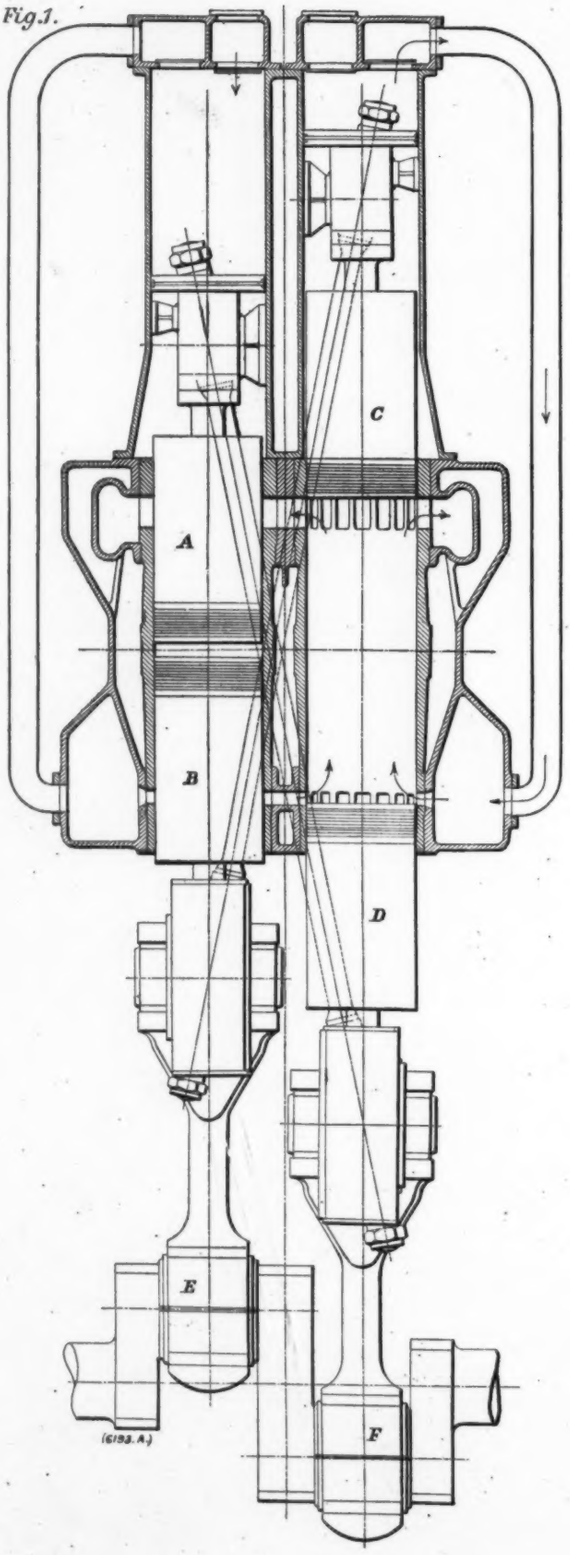
(For Description see Page

Fig. 1.



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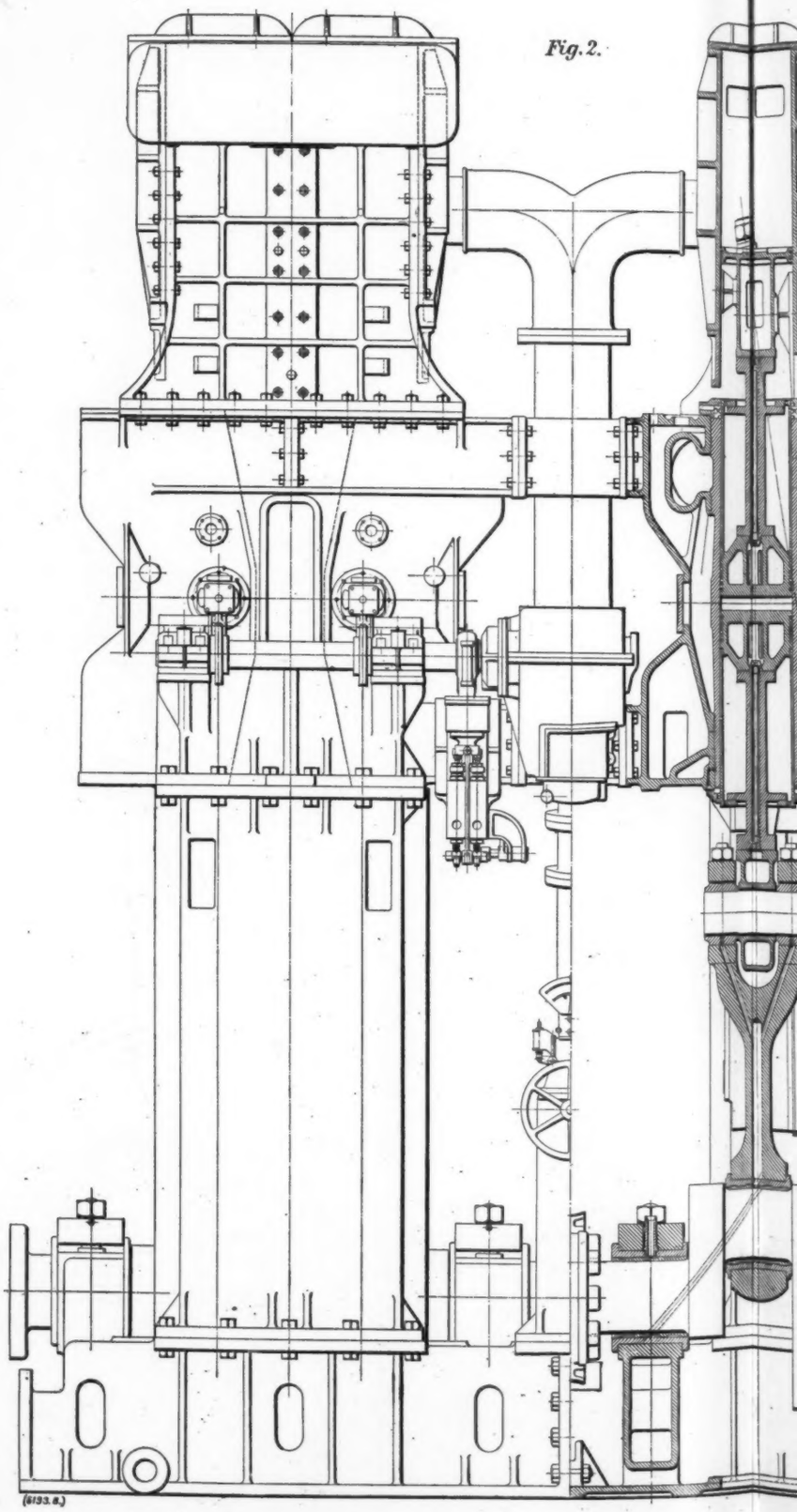

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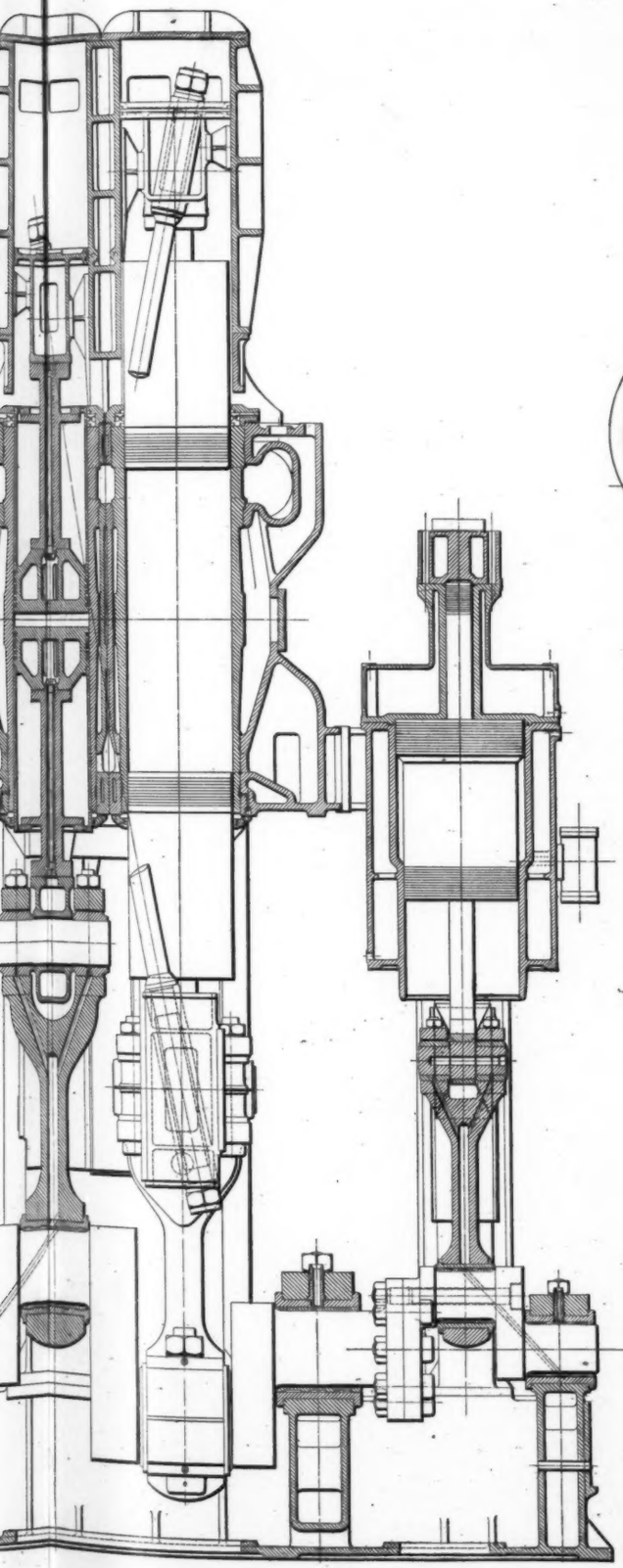

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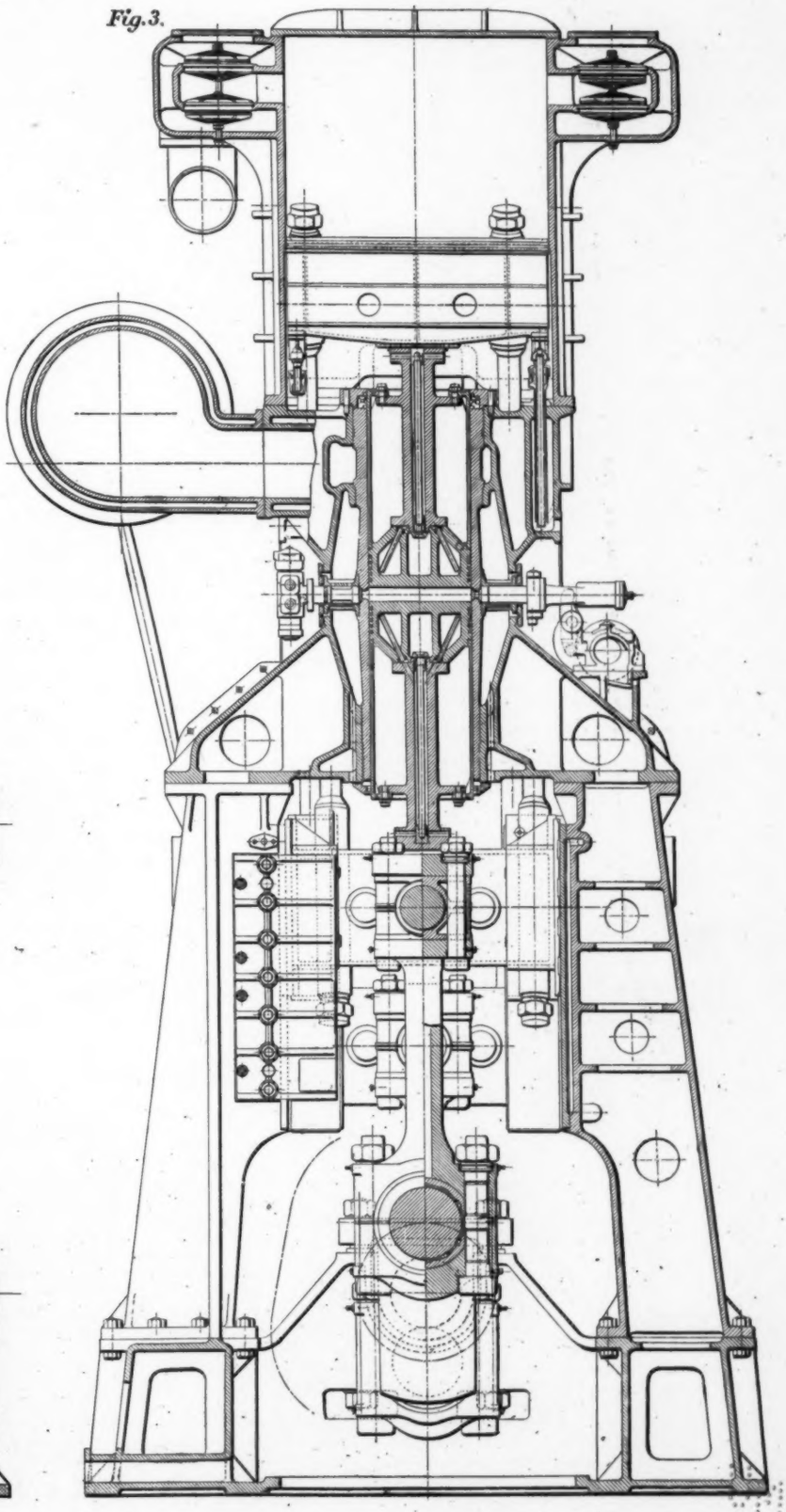

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For Advertisements, J. S. Allan, 18, Broadway, New York.

ADVERTISEMENT RATES.

The charge for advertisements classified under the Headings of Appointments Open, Situations Wanted, Tenders, &c., is four shillings for the first four lines or under, and one shilling per line up to one inch. The line averages seven words. When an advertisement measures an inch or more the charge is 12s. per inch. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

SUBSCRIPTIONS, HOME AND FOREIGN.

REVISED RATES.

"ENGINEERING" may be ordered from any newsagent in town or country and at railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance:—

For the United Kingdom	£3 3 0
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Thick ,, ,,	£3 3 0
For all other places abroad—	
Thin paper copies	£3 3 0
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When foreign subscriptions are sent by Post Office Orders, advice should be sent to the Publisher.

All accounts are payable to "ENGINEERING," LIMITED. Cheques should be crossed "The National Provincial and Union Bank of England, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford Street, Strand, W.C. 2.

Offices for Publication and Advertisements, 35 and 36, Bedford Street, Strand, London, W.C. 2.

We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.
TELEPHONE NUMBERS—3663 and 8598 GERRARD.

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With a Two-Page Plate of the CAMMELLAIRD-FULLAGAR MARINE OIL ENGINE.

NOTICE.

Owing to the enormous increases in the cost of paper, engravings, and printing charges generally, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 9d. to 1s. per copy. This increase dates from and includes the issue of Friday, January 2, 1920. The change will not apply to unexpired subscriptions. The revised rates for new subscriptions are given in the adjoining column.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions still imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 147.

ENGINEERING.

FRIDAY, JANUARY 30, 1920.

ECONOMISING TIME IN SHIP CONSTRUCTION.

THE imperative need for the adoption by British shipbuilders of any and every means that will conduce towards increased output of tonnage is being recognised with growing intensity. The rate of reconstruction of industry primarily depends upon transport, both overland and overseas, because increased food supply, with a reduction in cost, must lead to greater contentment, since any reduction in expenditure in the household is bound to influence the outlook of the worker and make him more satisfied with his remuneration. With this contentment will come later a desire to augment output. There is also gain in the increased supply of raw materials, with the resultant reduction in their price, and therefore in the cost and volume of output. Encouragement is found in the statistics regarding the tonnage of shipping built during the past year, issued this week by Lloyd's Register, and reviewed in another part of this issue. The figures for Britain are the more satisfactory, when it is borne in mind that a large part of the labour available is required for "reconditioning" ships used for war work. A significant feature is the enormously greater proportion of the world's tonnage built and building by foreign countries; indeed, our former supremacy in shipbuilding is seriously menaced. There is thus the greater need for intensive production in view of the fundamental considerations indicated, and every contribution to improvements in method of ship construction must be welcomed. Careful consideration should, therefore, be given to a helpful paper read by Mr. J. C. G. Cooper, at the North-East Coast Institution of Engineers and Shipbuilders, at Newcastle on Friday, the 23rd inst.

The title of the paper is "Some Suggested Developments in Laying Off for the Speeding-up of Ship Construction," and the author, in his introductory remarks, states that "higher building speeds may be obtained by an increased use of machinery, by additional labour intensively trained, or by shortening the existing methods so that the labour now available may be more economically used. The first of these means involves the laying out of much additional capital, and often takes some time to become effective; the second is almost impossible in face of the present attitude of labour; consequently it is to the third with a combination of as much as possible of the first two methods, that we must turn for an immediate solution to the admittedly difficult problem." The correctness of the author's statement of the position will be generally admitted, and the truth of his conclusion has been proved by the success which attended the application of the method which he advocates to the building of fighting ships during the war. Making all due allowances for the influence of other factors it remains true that the remarkable building performances recorded during the war period were made possible mainly by the improved methods employed in the shops and on the building berths, and not the least important of the improvements were those due to the more extensive use made of moulds and other information supplied by the moulding loft.

The case for increased tonnage of merchant ships gave prominence to the "Standard" and "Straight line" designs—both of which were evolved with a view to expedite construction—and both of which have, for various reasons, failed to satisfy either shipbuilder or shipowner. In spite of the comparative failure of these designs each had its good points, and to the development of some of the advantages of the "straight-line" design Mr. Cooper devotes the first part of his paper. With a view to reducing the time occupied in the preparation of the scrieve board for a new vessel, Mr. Cooper proposes to eliminate practically all the work of fairing the lines usually carried out on the mould-loft floor and to substitute a method of drawing in most of the sections by the use of arcs of circles, a suitably-chosen curve and straight lines. The lower parts of all frame sections are arcs of circles of suitable diameter, the upper parts of all frames are drawn in by means of a curve so chosen that it can be used for "tumble home" or, when reversed, for "flam," while the portion of frame between these two is a straight line. It is claimed that with the exception of a small part of the after body in the vicinity of the otter plate fairing is unnecessary, and that the saving in time due to the new method from the receipt of information in the loft to completion of scrieve board, is as much as 60 per cent. or 70 per cent. The chief advantage claimed in the matter of working the frames in the yard is that only one set iron need be made and used on the bending blocks. In practice there will undoubtedly be economy of time in the loft or frame shed in the matter of preparing the scrieve board, but any appreciable saving in time in the building of the ship seems to be doubtful, as under present conditions the scrieve board is usually ready at least as soon as the materials for keel and floors are delivered in the yard. In shipyards which have stock material available, and have facilities for an immediate start on floors, the system could be adopted with considerable advantage. At present it is a very common practice to prepare a scrieve board of which the lower part, embracing all the double-bottom floors, shell, intercostals, &c., is portable and is completed and placed in the hands of the frame squad before the upper part of the board. The adoption of Mr. Cooper's method in such a case would be of very considerable benefit, and would lead to an appreciable saving in time. The time gained in the bending of set irons for each frame referred to above would probably not amount to much, but it is always a step in the right direction.

The second suggestion which Mr. Cooper makes is much more hopeful in regard to possible time-saving, and is in effect a strong plea for a more extended use of the system of moulding shell plating. In introducing this part of his subject Mr. Cooper states that the suggestion to mould the outer bottom plating will probably be considered very revolutionary by a large number of shipbuilders, "especially those whose yards are not so well equipped as are our larger establishments." This would seem to indicate that the practice of moulding shell plating was largely confined to the larger yards, whereas the fact is that the smaller yards have, in many cases, already gone much farther in adopting the method than have the larger yards. The moulding of 65 per cent. of shell plating of a 450-ft. vessel of normal lines has already been done with success within our knowledge. Undoubtedly, however, the possibilities of the system of moulding the shell as a time-saver, have not been taken advantage of to anything like the full extent possible, and Mr. Cooper has done well to point out the advantages of the system and to assist in its practical application by the invention of a batten mould by means of which a very accurate development of plates having the maximum normal curve and twist is obtained. Of all the readily-available means of

speeding-up ship construction the extension of the system of moulding work in the sheds and completing before erection on the building berth offers the most encouraging prospects of success, and the strong advocacy of the method by such an authority on mould-loft work as Mr. Cooper should materially assist in dispelling any doubts that may linger in the minds of the more conservative shipbuilders.

FUEL FOR INTERNAL-COMBUSTION ENGINES.

THE enormous and ever-increasing use of internal-combustion engines compels serious attention to the question of the source whence a fuel for such engines is to be obtained in the future. Petrol has risen in price since the introduction of motor vehicles from a few pence to 3*s.* a gallon, and it is generally believed that a considerable further advance is imminent. The development of the suction-gas producer on the lines indicated by Colonel D. J. Smith at a recent meeting of the Institution of Mechanical Engineers, may do much to relieve the situation as regards the heavier class of motor vehicles. It is an attempt which not only shows a great promise of success, but which deserves every encouragement from the point of view of providing users with a very cheap form of fuel of British origin. Nevertheless, even if the success of the Smith producer or any kindred apparatus is as great as can be hoped for, there still remains an immense field in which some form of volatile liquid fuel forms the only practical source of power. Great things, at one time, were hoped of benzol, a home-made spirit produced as a by-product in the coking of coal. These expectations, however, have been disappointed, not so much on account of any fault of benzol as because the production of this substance is, and must remain, too small to exercise any appreciable effect upon the liquid fuel market.

For many years the eyes of engineers have been turned to alcohol as a possible substitute for petrol, and numerous attempts have been made to establish its use as a fuel for internal combustion engines. The difficulties in the way of the advocating of alcohol have been twofold; in the first place there was the fact that the Excise regulations, which were originally framed some thirty or forty years ago with regard to alcoholic beverages, placed an insuperable handicap on alcohol for power purposes. If, however, this had been the only obstacle to the use of alcohol as a fuel it is probable that the necessary modifications in the regulations might have been brought about, but the pressure to modify the legislation never grew to any formidable extent, because engineers realised that alcohol, as such, was by no means an ideal fuel. The principal objections to its use from the technical standpoint are: Firstly that its low vapour tension at ordinary temperatures makes it difficult to start an engine when cold. Secondly, one of the products of combustion, which is liable to be formed when alcohol is exploded with air, is acetic acid, which had a most destructive effect upon the cylinders and valves of the engine. Nevertheless the facts that the supply of the raw materials from which alcohol can be made, is unlimited, and that the production of alcohol is an easy and cheap manufacturing process, combined to maintain a considerable interest in the possibilities of this form of fuel. The usual source of alcohol is the fermentation either of natural sugar or of the sugars derived from starch. It was therefore natural that efforts towards the development of an alcoholic fuel for engines should be most general in the sugar-producing countries. The beet sugar industry of the Continent no doubt accounted largely for the interest taken by the French in the introduction of industrial alcohol, but it is to South Africa that we are indebted for the first practical development of an alcoholic fuel as a commercial enterprise of any magnitude.

South Africa, at the outbreak of war, found herself in a precarious position as regards petrol, since no mineral oils are found within the borders of any of the States of the Union. The sugar industry, however, flourishes in Natal, and no doubt the combination of these conditions was responsible for the invention of the form of alcoholic fuel now becoming generally known as "Natalite." Of this fuel, ether forms an important constituent, the composition of "Natalite" by weight being as follows: Ethyl alcohol (67 O. P), 54 per cent.; ether, 45 per cent.; and trimethylamine, 1 per cent. The function of the ether is to increase the vapour tension of the mixture and thus to render the fuel more readily volatisable at low temperatures than would be the case with alcohol alone. As ether is formed by the distillation of alcohol with sulphuric acid, the acid acting as a catalyst and being substantially unaffected by the process, the provision of a large quantity of ether is a matter of no great difficulty or expense. The third constituent, trimethylamine, $N(C.H_3)3$, is of the same nature as ammonia, methyl replacing the hydrogen atoms of ammonia. Trimethylamine, like ammonia, is strongly alkaline, and neutralises the acetic acid which is formed when alcohol is exploded with a limited supply of air. It also acts as a denaturant to render the alcohol undrinkable. Originally ammonia to the extent of 0·5 per cent. by weight was used as the necessary base, together with 0·02 per cent. of white arsenic as a denaturant, but the trimethylamine not only combines these functions, but having a lower boiling-point than ammonia is preferable to the latter substance on account of being less liable to separate out from the fuel.

As regards the physical properties of "Natalite," especially in respect of ease of volatilisation, the following figures may be quoted from a report made by Professor Vivian B. Lewes, when the fuel was first introduced:—

Vapour Pressure in Inches of Mercury.

Temperature.	Pratts' Perfection Motor Spirit.	Methylated Alcohol.	Natalite.
60	1·4	1·1	1·9
65	2·6	1·8	3·6
70	3·6	2·7	4·9
75	4·8	3·6	6·8
80	5·9	4·7	8·2
85	7·1	5·7	10·2
90	8·2	6·9	12·3
95	9·3	8·0	14·5
100	10·5	9·2	16·9

It therefore appears that while alcohol is uniformly below petrol in point of volatility—hence the difficulty of starting up a cold engine with it—"Natalite" on the other hand, has a notably higher vapour pressure. The ether, to which this is due, also has the effect of raising the calorific value above that of alcohol alone, and although the mixture contains only about 95,000 British thermal units per gallon, as against 134,000 British thermal units for petrol, a higher thermal efficiency is obtained on account of the combined oxygen. The net result seems to be that when used in an ordinary car, without adjustment of the carburettor or the engine, "Natalite" will give from 85 per cent. to 95 per cent. of the mileage per gallon which is obtainable with petrol. These figures are taken from official tests. Among the minor, but nevertheless considerable, advantages claimed for the new fuel, is the fact that it will not mix with, and therefore thin the lubricating oil, and, further, if the spirit catches fire accidentally, it can be extinguished with water.

"Natalite" is manufactured by the Natal Cane By-Products Company, who are turning out 3,000 gallons per day from their factory at Durban, and its use has become general in South Africa since the Act of 1916 which removed the restrictions on alcohol for power purposes. Another company, working under the same patents has a factory in operation in British East Africa, and several other plants are projected in Cape Colony and elsewhere where suitable refuse is available as raw material. The matter is also under consideration by the Australian and Indian Governments.

In view of the very unsatisfactory position in which not only Great Britain, but other parts of the Empire, are placed by the necessity of depending upon foreign sources of supply for motor fuel, the attempt to relieve the situation by means of a home-produced product will be watched with great interest. At present Government restriction upon alcoholic fuels in this country leave us very much at the mercy of the powerful interests which control the petrol market, but there is reason to hope that the authorities are alive to the situation. One would imagine that both the excise and the public health could be sufficiently safeguarded by some such relaxation of the restrictions as has been found practicable in South Africa, and then power alcohol could compete with petrol on an equal basis, to the advantage of all users of internal-combustion motors.

HIGH PRESSURE AND TEMPERATURE RESEARCHES.

WHERE we speak, in the present age, of things big and small, and of speeds, pressures and temperatures high and low, we should, a few decades ago, have expressed ourselves in the superlative and designated the conditions as extreme. The knowledge that light travels at the rate of 300,000 km. per second conveyed little to our minds, until we succeeded in speeding-up particles in discharge bulbs to velocities approaching that of light. These particles are not credited with more than 1/1,700 of the mass of the hydrogen atom, which was regarded as the smallest unit of mass in existence, and the atom itself is now considered to represent a little universe rather than a unit. Flying at 100 miles an hour is thought no more extraordinary than automobile travelling at half that speed, and possibly safer, in addition. The electric arc and the liquefaction of gases have familiarised the technical worker with temperature ranges of thousands of degrees, starting almost from absolute zero. When Haber proposed to synthetise ammonia by submitting the constituent gases to pressures and temperatures of hundreds of atmospheres and degrees Centigrade, engineers did not conceal their doubts as to the construction of suitable apparatus. A few days ago it was announced that Claude intends far to exceed these pressures and temperature in his ammonia process, and the engineers again shake their heads. Yet we are all familiar with pressures far above those suggested, and we altogether overrate pressures in other cases.

The Hon. Sir Charles Parsons, F.R.S., exemplified that fact by some very simple demonstrations last Friday, in his Royal Institution discourse on "Researches at High Pressures and Temperatures." He took two table knives in his hands and pressed blade against blade so as to dent them; the pressure on the boundary surface of the notch averaged, he said, 300 tons or 350 tons per square inch. The pressures on the knife-edges of a weighing machine were of the same order, and similar figures were also reached in a Brinell hardness tester which Sir Charles showed—a hand instrument of the size of a stout pencil, in which the hand compressed a spiral spring to the end of which a ball was attached. When a needle was broken or a piano wire strained to the point of breaking, the maximum tension was at the rate of about 150 tons per square inch. On the other hand, the pressures occurring in the chambers of large guns did not usually go beyond 20 tons per square inch, and the tensile stress on a ship in a heavy sea would not exceed 8 tons per square inch. Now this latter figure, a pressure of 7 tons or 8 tons per square inch, is the equivalent of 1,000 atmospheres (1,000 kg. per square centimetre), and the highest pressures used by P. W. Bridgman in his researches,* to which Sir Charles referred, amounted to 24,000 atmospheres, whilst Sir Charles Parsons himself has worked with pressures of hundreds and, momentarily, even of thousands of tons per square inch. It should be borne in mind, of course, that the pressures of Tammann, Johnston, Bridgman and others were uniform hydrostatic, while Sir Charles works with hydrostatic pressures in dies for hundreds and impact pressures (instantaneous) for thousands of tons per square inch.

All these investigations have a high geophysical importance, and it was to this aspect of the phenomena that Sir Charles Parsons first drew attention, to return to it in his final remarks. Our deepest shafts being only a little more than one mile in depth, Sir Charles had proposed in 1904 to sink a shaft 12 miles deep for exploring the region beneath us. There were, at that time, no properly-equipped geophysical laboratories in existence, but in 1911 Professor Frank D. Adams, of Montreal, com-

* See ENGINEERING, August 3, 1917, page 124.

menced experiments on the strength of rocks to resist the closing up of cavities under the conditions prevailing at great depth. He placed a block of granite or limestone in a shrunk-on cylinder of nickel steel and compressed the ends of the block by a hydraulic ram; holes of 0·05 in. bore, being 0·1 of the diameter of the block, had previously been drilled into the latter, one axially, one transversely.

When pressure alone was applied to the granite, the holes did not undergo alteration under a pressure equivalent to that existing at a depth of 30 miles below the Earth's surface; when the granite was also heated to 550 deg. C., a temperature corresponding to that existing at a depth of 11 miles, it stood a pressure equivalent to that due to a depth of 15 miles, but the steel container began to weaken. The limestone, though beginning to decompose at 450 deg. C., withstood at that temperature a pressure corresponding to a depth of 10 miles. Adams, therefore, concluded that the pressure and temperature prevailing at a depth of 11 miles would not cause cavities in granite to close up, and so far as these experiments went, Sir Charles considered them reassuring for his shaft scheme. In his hydrostatic experiments Bridgman further observed that a sealed glass tube could bear 24,000 atmospheres, corresponding to an Earth depth of 56 miles, for 3 hours without deformation. Since, however, seismologists assumed that earthquakes did not originate at depths exceeding 30 miles or 50 miles, and that at greater depths changes of form took place by plastic deformation and not by slips and fault formation, cavities, Sir Charles agreed, would probably close up at depths of more than 20 miles, when seismic waves appeared to change in character, the compressional waves being little affected in velocity, whilst the distortional waves lost half of their velocity.

It is noteworthy that water, which chemists and the advocates of the electrolytic dissociation theory regard as a complex substance, in spite of its apparent simplicity and homogeneity, retains its peculiarities under extreme pressure conditions which might be expected to favour a uniform structure. More than twenty years ago, Tammann distinguished four allotropic kinds of ice. Bridgman found, in 1911, five modifications, all more dense than water, and one of them stable within the range from —18 deg. C. at 4,500 atmosphere up to + 67 deg. at 20,000 atmospheres; we were not likely ever to observe such ice even at the bottom of the ocean, Sir Charles interposed. Ten years ago, he stated, Sir Richard Threlfall had, in the same place, traced the evolution of the theory of the effects of temperature and pressure on the allotropic forms of various substances with particular reference to graphite which, if it followed the general rule ought, in cooling from the molten condition, to crystallise as diamond. In briefly reviewing his own unique work in this field, which he has been carrying on since 1886, Sir Charles dwelt particularly on the engineering side of the subject, discussing the limits of temperature and pressure artificially attainable. If molten iron acted as a catalyst in the conversion of graphite into diamond, as it does in the transformation of diamond into graphite, the artificial diamond problem would long since have been solved. Unfortunately, Sir Charles had to state, no amount of pressure that we had succeeded in applying had reversed this reaction, whilst the synthesis of ammonia, likewise requiring a catalyst like iron, was reversible. From this point of view, then, he had little to add to the lecture on the "Formation of Diamonds" which he had delivered before the Institute of Metals in 1918,* and much of the experimental detail which he gave last Friday, could not profitably be described without reproducing our illustrations of his 2,000-ton press, fitted for heating by currents of 80,000 amperes, and of his vacuum furnaces and rifles.

With respect to mercury and steel, Sir Charles mentioned a curious observation of Bridgman's. Mercury penetrated steel, especially when hard and tempered, and caused the steel to burst at much lower pressures than when it was charged with oil or water, probably because the mercury amalgamated with the iron if the surface was clean and free from oxide. Sir Charles' containers or dies are cylindrical steel blocks, provided with one axial bore or two bores (from top and bottom) into which cylindrical rams fit, the bores and rams widening out conically above. When dealing with small charges the containers and rams were made of tungsten steel, hardened and tempered throughout; this steel would remain strong and not turn brittle up to 600 deg. C.; but in a one-bore (1½ in.) container cracks would finally form near the bottom of the die. Double re-entrant dies with two ½-in. rams were preferable, and were made fluid and gas-tight by mild steel caps; with charges occupying only a short length of the bore 300 tons per square inch could be applied repeatedly. Above 500 deg., however, the strength began to fail; yet electric heating of the charge should be possible, though the insulation difficulties would be great. The ram and container ends could further be reinforced, after the manner of the capped armour-piercing projectile, by fitting rings of copper or bronze round the necks of the rams, keeping the parallel parts of the noses as short as possible. In operation the copper rings would be flattened and squeezed against the necks and shoulders of the ram and also against the ends of the container and would transfer the heavy stress to other parts, thus permitting pressures up to 450 tons per square inch. For larger charges nickel steel, quenched in oil, was used; containers of a wall thickness equal to the bore diameter would stand internal pressure of 40 tons per square inch repeatedly, but at a pressure of 100 tons per square inch re-boring and re-packing became necessary after each experiment.

We have said that a great variety of chemical reactions were studied in the various apparatus. We notice that carborundum and sodium carbonate formed an endothermic explosive compound; when fused olivine was allowed to expand by releasing the pressure of 10 tons per square inch, a pumice stone was formed by the expansion of the water vapour absorbed by the molten mineral. In one of the rifle experiments, which promised the realisation of higher pressures than steel containers, a mild steel bullet was fired into the bore, tapering from 0·303 in. at the mouth down to 0·125 in. at the bottom, of a tungsten steel block; the block burst, but apparently not before the full pressure of 5,000 tons per square inch was reached. In another case, Mr. Stanley Cooke calculated that the temperature must have risen to 15,000 deg. or even 17,700 deg. C. If such experiments were repeated on a larger scale with 6-in. or 9-in. shells—to increase, not the instantaneous pressure, but its duration—at velocities of 5,000 ft. per second, or if the German gun which bombarded Paris were loaded with a solid steel projectile somewhat lighter than those actually used, and fired with a muzzle velocity of 6,000 ft. per second into a tapered hole, a pressure of 7,000 tons per square inch could be produced, and that seemed to represent the maximum pressure at present realisable.

Now, Sir Charles continued, 6,000 tons per square inch seemed to be roughly the pressure at the centre of the Earth, which Mr. Jeans estimated at something between 4,000 tons and 10,000 tons per square inch. For the centre of the more massive component of the binary star S. Herculis, Emden had suggested a pressure of 360,000,000 tons per square inch. If two such stars, of the density of iron, travelling initially at the rate of 30 miles per second, should collide, their velocities having increased to 450 miles per second owing to their mutual attraction, and the pressure in the centre would rise to 1,000,000,000 tons per square inch as they flattened out, and the heat generated would suffice to vaporise the whole mass 100,000 times over. The German gun could only produce 1/150,000th of that pressure. If stellar collisions occurred, however, we could conceive the formation of substances like radium by the endothermic combination of helium and lead, absorbing an energy 2,500,000 times the energy developed by an equal weight of trinitrotoluene. "The transformation of a minute fraction of the mass of two colliding stars would therefore be amply sufficient to absorb the whole energy of their collision."

These words brought Sir Charles back to his 12 miles-shaft scheme. We knew little about the interior of our Earth. The deepest shaft in existence of the Morro Velho, in Brazil, is 6,400 ft. vertically below the surface. On the Rand, the City Deep Company planned a vertical shaft 7,000 ft. deep, 20 ft. in diameter. The rapid sinking record of the Crown Mines shaft, also circular, 20 ft. in diameter, was 310 ft. in one month. For deeper shafts special methods of cooling would be required; the heat might, for example, be carried upward by means of brine circulating in pipes.

The hydraulic pressure at the bottom of the 12-miles shaft would be 12 tons per square inch; the air pressure upon the miners would be doubled every 2 miles or 3 miles, and the air temperature itself would rise to 100 deg. F. Hence airtight partitions would have to be placed across the shaft every mile or two to carry on ventilation, with pumps to deliver the foul air upwards, and expanders to allow the fresh air to descend. Another plan would be to generate liquid air on a large scale at the shaft mouth, and send it down the shaft in vacuum-jacketed pipes, from which it would be allowed to escape through taps at such places where cooling was required. This method would afford good fresh air to the miners in addition to ample cooling. Shields might become necessary to protect the miners from the splinting of the rock caused by the intense compression stress. Sir Charles did not dwell on other difficulties. In 1904 he had thought that the shaft might be sunk in eighty years; last week he reduced his time estimate to fifty years. It might cost 10,000,000*l.*, at present prices, he added. A serious start of his shaft might satisfy Sir Charles Parsons, even if the project were not tied down to the full 12 miles. Our ignorance concerning the Earth on which we live is certainly deplorable, and it is of little credit to an age, which excels in daring, wastes tens of millions without compunction, and which has learnt to rise miles into the air, that we have not yet penetrated by more than 1 mile into our solid Earth.

* See ENGINEERING, May 3, 1918, p. 489.

SPONTANEOUS IGNITION-TEMPERATURES OF LIQUID FUELS.

STATEMENTS of ignition temperatures require specification of the conditions. Iron wire may be burned in a candle flame, and paper may refuse to burn on a bright coal fire. To say that coal gas ignites at 878 deg. C. and benzene vapour at 1,033 deg. does not necessarily mean that the gas or vapour will catch fire at that temperature. It depends upon the gas pressure, the proportions, at the actual spot, of gas and air and of the moisture, and on many other factors—whether the gas be stationary or flowing, whether the ignition be attempted by a match, a spark or a glowing wire, from above or below, &c. The vapours escaping from the petroleum in oilfields may apparently cause explosions when they come in contact with some glowing carbonaceous matter adhering to an engine cylinder, though not by contact with the hot cylinder itself. Hence the great variety of methods of determining ignition temperatures, and the great diversity of values found. In the case of hydrogen-oxygen machines, which have received more study than any other explosive gas mixtures, we have the choice of ignition points ranging from 514 deg. up to 845 deg. We may probably disregard the extremely high values of Gautier and Hélier; but we know on the other hand that, given sufficient time, hydrogen and oxygen will combine almost at any temperature. The time factor is certainly very important. Most investigators therefore stipulate immediate ignition in their definition of ignition temperatures, and try to eliminate the time factor in their experimental methods.

Mr. Harold Moore, M.Sc., took a different standpoint in the paper on "The Spontaneous Ignition-Temperatures of Liquid Fuels," which he read before the Institution of Petroleum Technologists on January 20. He defined the spontaneous ignition-temperature as that temperature at which a substance surrounded by oxygen or air at the same temperature, will burst into flame without the application of any spark or other high local temperature. He did not speak of immediate ignition, and for reasons which will presently be explained, and which appear sound, he preferred in fact to

accept as ignition-temperature the temperature below which the fuel mixture refuses to ignite, however long it be maintained at a lower temperature. The case he dealt with is essentially that of the Diesel engine proper, not that of the hot-bulb semi-Diesel.

It would obviously be best to determine the ignition points of the fuel within the engine itself; but all temperature determinations of gases in motion are exceedingly difficult, even in the laboratory, and we have to fall back on other ways. Mr. Moore has modified the method used by Constam and Schläpfer in 1913, who allowed a drop of the fuel to fall into a platinum crucible the temperature of which was determined by a thermocouple. Mr. Moore fits his crucible exactly into a diffusion block of steel or cast-iron, 100 mm. in diameter and 75 mm. thick, which is provided with deep grooves on its lower surface to present a greater heating area to the gas burner underneath; the temperature of the ignition-meter is read on a thermometer or a Whipple resistance pyrometer inserted in bores in the block. There are two holes in the crucible cover, one for admitting the drop of substance under test, the other for admitting air or oxygen in measured quantities; these gases are preheated by passing through holes drilled into the block. The crucible and air in it are thus fairly at the same temperature, and the drop of liquid fuel may or may not ignite at once or after a "wait period." The lowest temperature at which explosion occurs is taken as the ignition temperature. Observations made by different operators agreed, Mr. Moore stated, mostly within 3 deg., except in the case of some mixtures, and it was shown that the experimental conditions could be varied to a certain extent.

The rate of supply of oxygen (in bubbles) and of the fuel (from 1 to 4 drops per second) made very little difference in the ignition-temperatures, but the wait periods varied, decreasing in the case of a petrol, *e.g.*, from 38 seconds at a meter temperature of 284 deg. C. (which is accepted as ignition temperature) with fair regularity, down to 1·4 second as the meter temperature was raised to 320 deg. Most of the ignition temperatures so determined were considerably lower than those found in actual engine tests, however, and that is to be expected since, owing to the absence of turbulence in the meter and to other factors, the conditions are not directly comparable. But the differences are considerable, and some of the results appear rather discordant. Whilst it was found, as mentioned, that the rate of oxygen supply made little difference in the ignition points, experiments in air gave less concordant and higher values than in oxygen, the difference amounting to as much as 200 deg. C. sometimes. Both these facts had been recognised before, but as the air is compressed in internal-combustion engines and the oxygen thus concentrated in a sense, tests in oxygen are generally preferred, though Mr. Moore agreed with Dr. Thole that the air-tests of fuel mixtures are far more sensitive often to changes in the proportions than tests conducted in oxygen. Again Mr. Moore observed that when he mixed his oxygen with increasing percentages of carbon dioxide, the ignition-point of a kerosene only rose from 254 deg. to 261 deg., as the percentage of oxygen was reduced from 100 to 30. He noticed that the sound of the explosion became fainter as the CO_2 increased, but he did not discuss this point. From the experiments of Major W. T. David* it would appear that the presence of CO_2 diminishes the maximum pressure developed, and slows down the rate of combustion. Since a period of "silent combustion" obviously precedes the actual explosion, and this silent combustion is favoured by the catalytic action of the crucible, Mr. Moore tried crucibles of platinum, nickel, silica and porcelain. Sometimes he dispensed with a special crucible, using the cavity in the block as such. These materials hardly appeared to affect the ignition point of a petrol, and the wait period; the latter observation is rather striking, considering that both fuel spray and fuel vapour will be present in the crucible. In the case of pure hydrogen the crucible material—porcelain, silica and nickel—did make a difference, the ignition points observed being 686 deg., 678 deg. and 619 deg. The catalytic influence of the nickel, which became coated with oxide in the course of the experiments, was marked.

These factors assume further importance in the case of fuel mixtures of which Mr. Moore has examined a large number not previously tested for ignition temperatures—petroleums, petroleum distillates, tars and tar distillates, shale oils, and chemical compounds. Mixing fuels like creosote and cannel oil, consisting of two constituents of strongly differing volatility and ignition points, Mr. Moore obtained sometimes steadily rising curves, but more frequently curves showing an abrupt rise at a certain mixture-ratio, indicating that a small addition of a constituent of higher (or lower) ignition point had little influence on the ignition point of the mixture.

It is noteworthy that aromatic compounds have higher ignition points than aliphatic (fatty) compounds, and saturated and complex hydrocarbons and compounds show a higher ignition point than bodies of simple and unsaturated molecules. The relations are not simple, however, and we must not be tempted into photochemical theorising. But Mr. Moore's ignition meter, which he modified in some of his experiments, seems, in spite of all difficulties, to be well suited to assist the engineer in internal-combustion engine problems. Thermal efficiency calls for high compression, but the compression temperature must not exceed the temperature of the spontaneous ignition of the charge, lest pre-ignition and knocking result. The temperature corresponding to adiabatic compression may be calculated from the formula $T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$ where T_1 and T_2 are the initial and final temperatures of the charge, P_1 and P_2 the pressures, and n is the ratio of the specific heat at constant volume to that of constant pressure. For air $n = 1{\cdot}408$ under adiabatic compression; for the conditions in the engine Mr. Moore takes $n = 1{\cdot}35$. Assuming then a temperature of 30 deg. C. for the induction gas, he deduces a graph for the temperature of the charge at a given compression. Taking the compression ratio as ordinate and the ignition temperature as abscissa, that curve would, in the case of a petrol engine, indicate the maximum compression limit for any given ignition point. In the case of a Diesel engine the same curve would mark the minimum pressure required for burning the fuel. Local heating of parts of the cylinder or cooling of the charge by the air blast would, in either case, produce discrepancies between the theoretical and practical results, and we have to bear in mind that the ignition temperature may, to an unknown extent, be influenced by the pressure, and that we have to distinguish between constant-volume and constant-pressure cycles. From various engine trials of certain fuels Mr. Moore has, however, been able to plot curves of ignition points against the maximum and minimum compression pressure desirable for smooth working of Diesel engines. These curves will enable the engineer to decide, either which compression stroke would be suitable for a particular engine or, when variation of the compression is not advisable in the case of car engines, *e.g.*, how to mix his benzol and alcohol in suitable proportions.

* See ENGINEERING, September 5, 1919, page 300.

THE INSTITUTION OF MECHANICAL ENGINEERS.

AN ordinary general meeting of the above Institution was held on Friday last, the 23rd inst., at the Institution House, Storey's Gate, the chair being taken—in the absence through illness of the president, Dr. Hopkinson—by Mr. Mark H. Robinson, vice-president.

ELECTION OF OFFICERS.

The ordinary formal business having been despatched, the chairman submitted to the meeting the list of officers retiring and the nominations made. He stated that, in accordance with Article 23, the president, two vice-presidents and seven members of council would retire at the annual general meeting in February. The list of those retiring was as follows:—President: Dr. Edward Hopkinson. Vice-presidents: Sir Robert A. Hadfield, Bart., D.Sc., F.R.S., and the Right Hon. Lord Weir, P.C. (appointed during the year). As members of council: Dr. H. S. Hele-Shaw, LL.D., F.R.S.; Mr. Christopher W. James (appointed during the year); Mr. Bowman Malcolm; Mr. Donald B. Morison; Sir Vincent L. Raven, K.B.E.; and Mr. D. E. Roberts (appointed during the year).

The chairman next announced that the following gentlemen had been nominated by the council for election, with their consent:—As president: Captain H. Riall Sankey, C.B., R.E. As vice-presidents: Sir R. A. Hadfield and Lord Weir. As members of council: Dr. Hele-Shaw, Mr. C. W. James, Mr. D. B. Morison, Sir Vincent L. Raven and Mr. D. E. Roberts.

The council had also nominated for election, with their consent, as members of council, the following gentlemen: Mr. Richard W. Allen, C.B.E.; Sir George J. Carter, K.B.E.; Mr. William Mills; and Mr. L. St. L. Pendred.

In response to invitation from the chair, under By-law 26, the further names of Colonel A. E. Davidson, D.S.O., R.E. (proposed by Mr. H. G. Burford) and Mr. F. W. C. Dean (proposed by Mr. W. H. Turton), were submitted. These additional names will be duly included in the ballot-papers issued to the members.

The secretary then stated that 149 candidates had been elected as members and associate members, and that seven transferences had been made from the class of associate member to that of member.

MODIFICATION OF BY-LAWS.

The chairman announced that notice of certain changes in the by-laws had been circulated among members. These would come up for discussion at the next meeting. The proposed alterations had been under consideration for many years, and had been settled after the fullest discussion. Certain changes had been made in the ages of entry into the different classes, the inspiring motive being, in the first place, to give some advantage to those who had passed the examinations instituted a few years ago. On the other hand, provision had been made for men whose tastes and abilities might not lie in the direction of examinations, but who had, nevertheless, gained such experience as entitled them to entry.

A small increase in the subscriptions had also been proposed, namely, from 3*l.* to 4*l.*, to which the speaker did not consider that members would object, regard being had to the necessity for increased salaries to staff and the prevailing high cost of work and materials. The sum to be asked was, even so, less than the subscriptions paid in the cases of other Institutions. It was proposed to advance the subscription rate for associate members from 2*l.* 10*s.* to 3*l.* It was felt that associates should also pay this sum, as it was desirable that that grade should really be regarded as an honour conferred upon men who were not engineers, but whose admission would be creditable to the Institution.

The beginnings of a scheme had been evolved for the development of local branches. The intention was to restrict such development of local branches to the places where the branches would be likely to be of real service to members. Mr. Robinson also referred to a proposed alteration of Article 23, which, under the Companies' Act, would require a special meeting. The object in view was to create a grade of "Past Vice-President."

Notices of amendments to these proposals had been received, and the secretary proceeded to summarise these. They dealt with various points, such as examinations, subscriptions, &c., and will be formally discussed at the next meeting.

UTILIZATION OF WATER-POWER.

The paper set down for reading and discussion was entitled "Recent Advances in Utilisation of Water-Power," by Mr. Eric M. Bergstrom, of London, Associate Member. This was read in abstract by the author, and partly discussed. We commence the printing in full of this paper on page 140 of the present issue. The discussion was opened by Professor W. E. Dalby, who said that the paper they had just heard would, he thought, become a classic. The data recorded would be invaluable to many in the future, and members were greatly in the author's debt. He well remembered the great interest aroused when the Niagara Power Station was installed, and was sorry that Dr. Unwin was not present at the meeting, inasmuch as he had

been chairman of the Commission which sat in London to consider whether the then schemes proposed were feasible. When the Niagara station was compared with the enormous station dealt with in the paper it appeared quite a small affair, with its 5,000-h.p. turbines. He had also spent some time in investigating the smaller power station at Lauterbrunnen, in Switzerland—a typical Swiss station. A point of interest about the hydraulic installations referred to in the paper was the simplicity of design of the vertical runners, with the bearings placed on the top of the runners, and everything easily accessible. Another point was the tremendous increase in efficiency attained by the plants. Not many years ago, it was an article of faith that, whatever happened, a turbine could not yield a greater efficiency than 80 per cent. Now, however, there was an authentic record of 90 per cent. There was no mystery in the improvement; by attention to stream line flow and avoidance of eddies, skin friction and eddying had been reduced. He would point out one line of study which would, he thought, prove of interest, namely, a comparison between the theory and efficiency—90 per cent. and over—of the steam turbine and the theory of the water turbine, also with an efficiency of 90 per cent. and over. After all, the steam turbine was only a water turbine with another variable factor—the expansion of the steam as the pressure fell. In the water turbine there was no change of volume to give trouble; as the water flowed through the turbine the volume remained constant, thus simplifying the problem.

The chairman then adjourned the discussion. He then announced that the paper would be again discussed at Manchester, and also at Cardiff, on Thursday, the 29th inst., and he gave notice of an informal meeting to be held at the Institution House, on Friday, January 30, at 8 o'clock p.m. The council hoped for a good attendance at this informal meeting.

Further, Mr. Robinson announced that a meeting of graduates would take place on Monday, February 9 next, at 8 o'clock in the evening, and on that occasion Dr. C. C. Carpenter would lecture on "Fuels." All classes of members were invited.

The Rhone Engine.

Finally the chairman stated that Mr. Richard Allen, son of Mr. W. H. Allen, of the Queen's Engineering Works, Bedford, had kindly consented to make some remarks on the Rhone engine which had been presented by his father to the Institution. This presentation was, he thought, a very delicate compliment to the Institution. Mr. Allen had given something which might be looked upon as the product of war work, and which was not likely to be repeated for general purposes. It was quite removed from any reproach that it merely illustrated work done at Bedford. Although it remained an example of very beautiful work which had been done there, it had no commercial meaning.

Mr. Richard Allen, in presenting the Rhone engine to the Institution on behalf of his father stated it was offered merely as a memento of war work. The Gnome engine had been the means of making great advances in aviation, but that engine had considerable defects, among them being that it could not be throttled down. M. Verdi, in 1910, turned his attention to this point and in 1912 succeeded in his efforts. His work was financed by friends in Lyons, and the engine was therefore called the Rhone engine. In 1913 it made a record by crossing the Alps. In 1914, when war broke out, no suitable steels were made in this country for engines of this type. That was soon afterwards remedied at Sheffield. The engine was not only a memento of the war, but a record of the work of women during the war, as it had been almost wholly produced by this class of labour.

The proceedings of the evening terminated by a few appropriate words by Mr. M. Robinson accepting the gift on behalf of the Institution.

The Simplon Tunnel.—Work on the Simplon Tunnel II had to be suspended in July, 1918, owing to the dearth of labour and of materials. The operations were resumed at the beginning of November last. By the end of the year 1919, 17,305 m. of a total tunnel length of 19,825 m., that is 87·3 per cent., had been completed, the tunnel driven from the South having a length of 8,524 m., and that from the North a length of 8,781 m.

NOTES.

Arc Welding Developments.

There can be no doubt but that both blowpipe and electric welding are making headway. Both processes have now been available for a considerable number of years, and much good work has been done. Unfortunately, however, much bad work has also been done, and the systems as applied to engineering practice have to contend with much prejudice which is not altogether undeserved. It would not perhaps be fair to say that these methods lend themselves more readily to indifferent work than other processes of joining metals, but they certainly lend themselves to a type of indifferent work which is difficult to detect by superficial examination. The advances which the last few years have seen in many directions with these welding methods may be partly attributed to the gradual building up of a body of workpeople who have experience of the subject, perhaps more, however, may it be attributed to a general spread of the specialised knowledge required and a better realisation among firms and engineers who use the processes, what exactly they are trying to do. There is, however, another cause of progress. Long-continued and distributed experience in blowpipe and electric welding, as in other mechanical arts, leads to improvement in methods such that good work is rendered more easy of accomplishment and the vagaries of the individual workmen are given less weight. Of these improvements the replacement of the carbon, or bare metal electrode, by electrodes provided with an extruding flux, is certainly one of the most important. Such electrodes can be specially prepared for any particular type of work. The manufacture of such special electrodes has been taken up on an extensive scale by Messrs. Alloy Welding Processes, Limited, of 14 to 16, Cockspur-street, S.W. 1. Electrodes of this type form a definite advance in the process, and particularly leave less to the workman by forming a liquid flux over the molten joint, and so protect it from contamination from the air. By combining a suitable flux and a suitable metal in the electrode used it is now possible to supply material which will ensure that the metal of the weld shall not be inferior to the metal of the parts welded. An interesting development is the manufacture of tipped tools by fusing a layer of high-speed steel from a special electrode on to a mild steel shank. It is further worthy of note that the technical staff of Alloy Welding Processes was concerned with the all-welded steel barge which was constructed for the Admiralty in 1918. This barge is giving excellent service. The building of this barge probably shares with the repairs to the machinery of the damaged German steamers, which was carried out in the United States, the distinction of being one of the most striking welding feats carried out during the war. As a further considerable development the company is now concerned with the welding of a steel-framed building which is being erected at Brixton.

Application of Ore-Froth Flotation.

Under the presidency of Mr. Hugh K. Picard, himself a pioneer of flotation, the Institution of Mining and Metallurgy has recently discussed three flotation papers in succession. The first of these was by Mr. Harvey, on "The Development of Galena Flotation at the Central Mine, Broken Hill." The second, by Mr. H. L. Sulman, on the "Study of Flotation," we noticed at some length in our issues of November 28 and December 26 last on pages 723 and 860. We may now add that the January Bulletin of the Institution contains some very appropriate and partly very critical comments on the paper by Mr. Emil Hatschek and the detailed reply to the discussion by Mr. Sulman, who has been awarded the gold medal of the Institution for this paper. The third paper, by Mr. Walter Broadbridge, on "Froth Flotation: Its Commercial Application and its Influence on Modern Concentration and Smelting Practice," was read on January 22. Mr. Broadbridge dealt with his wide subject under the headings of evolution of apparatus for the agitation and aeration of the pulp, reagents and frothing agents, working of the process, and the influences of the adoption of flotation processes on ore reduction methods and smelting practice—on the whole in a very able, commendable manner. It would have been preferable, however, to have had illustrations of plant in the place of the diagrams of patent-specification type, and one would welcome literature references, which are altogether absent. We further regret that the cost question is not discussed. But cost estimates, unless very complete, are not satisfactory, and every author has to limit himself. Mr. Broadbridge was further limited by falling ill when his paper was due. His long and wide experience in flotation makes his paper all the more valuable, because the flotation literature has so far come mainly from America and Australia. As to costs he remarked that flotation had not increased expense, rather decreased it; that may not sound encouraging, but we have to bear in mind that, while flotation has greatly increased the recoveries and rendered former waste material available, it has also necessitated important changes in the ore reduction and smelting, changes which, though of the nature of improvements, affect the financial balance especially in transition periods. His account of his own experience at the Braden Copper Company, Chile, where subsequently the Inspiration Copper Company was started on flotation principles, is particularly interesting in this and other respects. Flotation units may not always be so simple, compact and low in plant and working costs as he states in general, and they are not likely altogether to supersede gravity concentration; the intended separation of the minerals is not always complete, as we gather from recent reports by the United States Bureau of Mines. But flotation has achieved a great deal and has reduced manual labour to a minimum. Mr. Broadbridge recommends that the ratio of water to solid should be kept low, say, at 3 : 1 or 4 : 1—too thin a pulp is not suitable—and that the ore should be crushed to a regular size, avoiding oversize of grains while admitting a certain percentage of slimes. As the froth collected might be very compact and difficult to handle, ample grade should be allowed for the overflow into launders, lest too much water be required to break the froth down. Smelting of the purer concentrates, formerly largely effected in blast furnaces, is now much simplified, and mostly effected in reverberatory furnaces with coal-dust fuel. Precipitation of the fine flue dust by the Cottrell process may have to follow. As regards the minerals amenable to flotation, Dr. Edser and Mr. L. A. Wood demonstrated at the meeting for the first time the successful flotation of cassiterite, tin oxide, both from Algiers and from Cornwall. The laboratory aeration machine used was a vertical cylinder, the rotating vertical shaft of which bears above a cruciform impeller, four blades being set in a cross at angles of 45 deg. to the horizontal; the air is sucked in through a pipe entering the bottom of the cylinder, and the froth comes out at the top, flowing down an inclined tray. The frothing agent used was soap, and as the water was hard, it had to be softened with soda first—this would of course be necessary in practice as well.

The Metropolitan-Vickers Electrical Company, Limited.—At the request of the Works and Staff Committees a course of lectures has been arranged to take place in the "A" Punch Canteen, Manchester, as follows: February 5, "The New Spirit in Industry"; February 12, "The Control of Electrical Machinery"; February 19, "Education and Industry"; February 26, "Patternmaking, with Special Reference to Plate Moulding"; March 4, "The Steam Turbine"; March 11, "The Legitimate Sphere of Trade Unionism"; March 18, "The English Banking System"; March 25, "The Economics of Industry."

Institution of Naval Architects.—The annual meetings of the Institution will take place on Wednesday, March 24, and the two following days, in the Hall of the Royal Society of Arts, John-street, Adelphi, W.C. The annual dinner will be given on Wednesday, March 24, at 7.30 p.m., in the Grand Hall, Connaught Rooms, Great Queen-street, Kingsway, W.C. A gold medal will be awarded by the council to any person not being a member or associate member of council who shall at the forthcoming meetings read a paper which, in the judgment of the council, is deemed to be of exceptional merit. The council will also offer a premium of books or instruments to the reader of any paper, not being a member or associate member of council, which paper, in the judgment of the council, merits this distinction.

INDUSTRIAL NOTES.

In an annual review for 1919, on employment, wages, &c., issued by the Ministry of Labour, it is shown that the average percentage of unemployment among members of trade unions paying unemployed benefit was 2·4 for the year. This compares with 0·8 in 1918, 0·7 in 1917, 0·4 in 1916, 1·1 in 1915, 3·3 in 1914 and 2·1 in 1913. Coal miners were well employed throughout 1919; the number of men working at coal mines increased during the year to such an extent that in December it was over 20 per cent. greater than at the end of 1918. In the pig-iron industry and at iron and steel works, employment continued good in the first six months, though the volume of work was less than in 1918; later, these branches of industry were seriously affected by strikes of coal miners, railwaymen and ironmoulders. At the end of the year, employment was good, on the whole, at blast furnaces, and fairly good at iron and steel works. Until September employment was fairly good for men regularly attached to the engineering trades; in the closing months, the strike of moulders caused much unemployment and short time.

The workpeople whose rates of wages were reported as changed in 1919 numbered 5,647,000, the aggregate increase in the weekly wages of those affected being 2,111,000*l.* (the figures for 1918 being 5,998,000 workpeople and 2,998,000*l.*). In the coal-mining industry, an advance was granted of 2*s.* per day to workpeople 16 years of age or over and of 1*s.* a day to those under 16, with effect as from January 9, as a result of the recommendations of the Coal Industry Commission. Percentage additions to piecework prices were also granted to compensate for reduction in working hours. In the engineering, boilermaking and shipbuilding industries, increases in basis rates were given to certain classes of workmen in various districts. In addition, a general advance of 5*s.* per week was granted, at the end of November, to men 18 years of age and over, bringing the general increase over pre-war rates for time workers up to 33*s.* 6*d.* a week, plus a bonus of 12½ per cent. on total earnings. The advance of 5*s.* per week was extended to workers in many other metal trades.

The marked feature of the industrial situation in 1919 was the reduction in weekly working hours in the principal industries. At the end of 1918, the hours usually worked in these industries ranged generally from 48 to 60 per week, whereas by the end of 1919, the most usual range was from 44 to 48 per week. The number of workpeople whose recognised hours of labour were reported as having been reduced during 1919 (exclusive of seamen, agricultural labourers, police, &c.), was 6,400,000, the average reduction per head being 6½ hours per week, the aggregate reduction in weekly hours being 41,461,000.

The number of trade disputes causing a stoppage of work in 1919 was 1,413 (1,252 in 1918); the number of people involved was 2,581,000 (1,132,000 in 1918); the aggregate duration of the disputes was 34,483,000 working days (6,237,000 in 1918). This aggregate for 1919 was nearly equalled in 1893 and was exceeded in 1912.

At the end of 1918 the total membership of trade unions was 6,624,000 (5,547,000 in 1917), an increase of 19 per cent. over the 1917 total. The total number of male members was about 5,400,000, showing an increase of 16 per cent., and that of female members about 1,220,000, or an increase of 36 per cent. in the year. The following are some of the figures of membership for 1918, and increases for particular trades: Coal-mining, 964,000 members and 5 per cent.; iron and steel manufacture, 130,000 and 10 per cent.; ironfounding, engineering and shipbuilding, 760,000 and 13 per cent.; general labour, 1,102,000 and 50 per cent.

The following are the figures of the ballot in the moulders' strike: For resumption of work, 17,667; against, 11,263; majority for resumption, 6,404. As will be seen, the men who took the trouble to record their vote numbered only 28,930. Since about 50,000 moulders were directly involved in the dispute, over 21,000 abstained from taking part in the ballot. The strike commenced on September 20. The men are gradually returning to work as from Monday last.

Speaking on the subject, the general secretary of the Steam Engine Makers' Society states, in his report for January, that never was a more futile struggle entered upon. His society, together with others, had been undergoing a process of financial bleeding by reason of this strike, in regard to which the engineering trade as a whole had never been considered or consulted in the slightest degree, notwithstanding the fact that the trade unions outside those directly in dispute were, both in numbers and finance, far more involved and had interests of a far wider character.

Dealing before the Cambridge Chamber of Commerce last week with the recent railway strike, Sir Eric Geddes, Minister of Transport, said: ". . . The pre-war wages bill of the railways was 47,000,000*l.* per annum, the future normal wages bill will be 110,000,000*l.*—an increase of 63,000,000*l.*, or 134 per cent. This is partly due to the increased rates of pay, and partly to reduced hours. The whole of this extra and abnormal cost is provided for in the estimate for the new railway rates. As the cost of living falls and economies are effected, and we get unified control and improved conditions, you can look for reduced rates and fares. If the railways are prudently managed and trade continues to improve, you can look to a reduction on the present high rates, which have been imposed of necessity. I believe even with these extra charges for labour, the railways can thrive and carry the traffic of the country at reasonable rates. Although the railwaymen have not got all they wanted, I feel they have got a good and generous settlement. We have had assurance from the leaders of whole-hearted co-operation; and I believe that when the men realise what the settlement is and that we want to give reasonable remuneration for service, we shall get their co-operation. I think the railway unions to-day are really sounder and more sane than, and as patriotic as, any other union in the country. If we can get their co-operation, the money involved in the settlement will melt like snow in summer. The rates to-day have been forced up because the men have been in a condition of ferment. We have now established machinery to settle these things without strikes; and if it is worked in spirit as well as in letter, it will avoid strikes. The settlement, in my opinion, is a wise one. It is good for the men and the country and for trade."

The following resolution passed at a meeting of delegates of the National Union of Railwaymen, is taken from *The Railway Review* of the 23rd inst.:—"That this conference, having heard the reply of the Government to our resolutions and the further explanations of the general secretary, whilst fully appreciating the inclusion of our Irish brothers and the offer for grades not originally included, also the proposals for meeting the hardships of those whose combined rates are higher than the proposed new standards, again reaffirm our belief that the only equitable method of standardisation is by taking the highest maximum of each grade or group of grades, and whilst the only means to obtain this at present is by a general strike, recognise that such a course is unwise, and therefore decide to accept the settlement under protest, and instruct the general secretary to call a special general meeting immediately the final proposals for signalmen and other outstanding grades are completed. That this conference, after hearing the explanations upon a flat rate (of 1*l.*) to each member affected, as against the actual amount for those members whose basic rate would be higher than the combined war wage and original rate, by the general secretary, decide to accept the flat rate."

The Executive Council of the Operative Bricklayers' Society state that their demand from the Government in return for tackling the housing problem by getting the houses built instead of talking about them is the following:—

(1) Guaranteed full week for all operatives engaged upon housing. No man to lose time through forces over which he has no control, such as rain, &c. (2) Every bricklayer in the Army or Navy (not being a volunteer) to be released at once. (3) That non-essential building be suspended and tribunals set up in districts to examine all claims for building outside the housing schemes, and only by their sanction shall any such building proceed. Building trade unionists to have 50 per cent. representation on such tribunals. (4) That the rent of any cottage or flat under the housing scheme should not exceed 10*s.* per week. (5) That the Rents Restriction Act be extended until the supply of houses is equal to the demand. (6) In the event of the supply of labour being insufficient to meet the need, we are prepared to consider the permitting of overtime upon housing schemes only, but as a condition of such consideration every man must be employed; in other words, we will not sanction overtime for any scheme whilst other men are unemployed."

The resolution adds that these are practical answers to a pressing problem, and the bricklayers are prepared to start any day if these points are recognised. It is pointed out that during the last five years over 20,000 bricklayers have left the industry because it did not provide a living for them.

Electricians in Liverpool forming part of the Electrical Trades Union have been locked out since Monday evening, the 19th inst. The situation is rather involved, and the following is taken from a statement made by the hon. secretary of the local branch of the National Federated Electrical Association: A code of rules was agreed upon by the District Joint Industrial Council, formed of representatives of the employers and of the Electrical Trades Union, in equal numbers. The rules were forwarded for ratification to the National Joint Industrial Council. They were not ratified by the National Council, and were referred back to the District Council for reconsideration. When the District Council met, its trade union members said they were not prepared to consider any amendments to the rules as submitted to the National Council, and they all resigned from the District Council; the secretary of the Electrical Trades Union then demanded that the rules as agreed upon by the District Council be put in force at once, failing which all overtime would be stopped and other drastic measures would be adopted. The local employers, as members of the National Council, could not comply with this, and the result was that all Electrical Trades Union labour was withdrawn from four of the leading local firms; this was done notwithstanding the fact that the employers had requested that any action be deferred until after the meeting of the council of the National Federated Electrical Association in London on the 21st inst. The local members of the said association were therefore placed in the unenviable position of having to declare a general lock-out, not only in support of the four firms who were being victimised, but as a means of hastening a decision upon a point on which the local body of the Electrical Trades Union evidently considered themselves to be the sole arbitrators. At the meeting in London on the 21st inst., it was decided to approach the executive of the Electrical Trades Union, asking them if they were agreeable to submit the case to an arbitrator appointed by the Ministry of Labour, since the question involved other districts and was therefore a national one of the greatest importance to the industry.

THE WORLD'S SHIPBUILDING.

The efforts made by the shipbuilding nations of the world to replace the shipping losses due to the war are strikingly demonstrated by the statistics just published by Lloyd's Register. It appears from these statistics, which only include merchant vessels of 100 gross tons and upwards, that 2,483 ships, making 7,144,549 tons in all, have been launched during the year, but it must be borne in mind that many of these are still in the hands of the shipbuilders. It should also be noted that in these figures, and in those that follow, vessels fitted with internal-combustion engines and sailing ships provided with auxiliary power, are classed as steamers. Considerably more than half of the above-mentioned total has been contributed by the United States, and notable developments, all of which will be referred to later, have been made in the shipbuilding production of Japan, Holland and Sweden.

TABLE I.—*Showing the Number and Tonnage of Merchant Vessels Launched in the Principal Shipbuilding Districts in the United Kingdom during the Three Years* 1917–1919.

District.	Total 1919.		Total. 1918.		Total 1917.	
	No.	Tons. (Gross.)	No.	Tons. (Gross.)	No.	Tons. (Gross.)
Aberdeen	24	9,572	—	—	16	5,266
Barrow, Maryport and Workington	5	8,992	3	11,004	1	587
Belfast and Londonderry ..	37	213,720	23	148,259	19	148,057
Dundee	10	15,198	8	23,860	7	6,911
Clyde—						
Glasgow	136	337,030	41	188,736	41	185,551
Greenock ..	58	188,717	31	160,024	24	134,308
Hartlepools ..	20	82,233	25	100,413	13	65,622
Hull	48	20,326	5	25,480	18	20,037
Leith	14	20 300	11	20,421*	9	14,309
Liverpool	19	38,165	4	12,486	5	26,528
Middlesbro', Stockton and Whitby	36	119,943	24	109,298	23	109,306
Newcastle	64	239,836	55	266,594	52	231,907
Sunderland .	64	274,283	58	260,553	48	204,398

* Includes a sailing ship of 3,845 tons.

United Kingdom Production.—As far as this country is concerned the year's production, as was foreshadowed in our article on page 86 *ante*, has been distinctly disappointing. The vessels launched in the United Kingdom during the past year number 612, and have an aggregate gross tonnage of 1,620,442, which is only about 20 per cent. more than the previous year's tonnage. In this connection, however, it must be remembered that naval shipbuilding was continued on a considerable scale during the first half of the year, and the time that has elapsed since it ceased has not been sufficient to affect the merchant tonnage launched. Actually the tonnage in hand in British yards at the end of the year amounted to over 38 per cent. of the world's tonnage building, but the British tonnage launched during 1919 amounted to less than 23 per cent. of the world's total. In the pre-war record shipbuilding year of 1913 British yards accounted for about 58 per cent. of the tonnage launched in the whole world.

THE WORLD'S SHIPBUILDING.

TABLE II.—SHOWING THE NUMBER AND TONNAGE OF MERCHANT VESSELS OF 100 TONS GROSS AND UPWARDS LAUNCHED IN THE VARIOUS COUNTRIES OF THE WORLD DURING THE YEARS 1892-1919.

Year.	United Kingdom.		Dominions. —		Dominions. Canadian Lake Ports.		Austria-Hungary.		Denmark.		France.		Germany.		Holland.		Italy.		Japan.		Norway.		Sweden.		United States. Coast.		United States. Great Lakes.		Other Countries.		Totals.		Year.
	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.	
1892	681	1,109,950	58	19,792	No	Returns	7	2,302	22	12,707	19	17,228	73	64,888	15	14,368	21	13,888	—	—	42	24,572	12	4,659	73	62,583	No	Returns	28	11,103	1,051	1,358,045	1892
1893	536	836,383	41	17,089	No	Returns	6	7,435	18	10,719	22	20,337	65	60,167	8	1,339	21	10,626	3	1,132	30	16,552	18	6,566	36	27,174	No	Returns	42	11,222	846	1,026,741	1893
1894	614	1,046,508	26	6,055	1	748	5	1,703	16	7,300	28	19,636	77	119,702	41	15,360	10	5,396	14	3,173	25	17,169	14	7,310	36	44,847	7	22,047	18	6,584	932	1,323,538	1894
1895	579	950,967	23	6,105	7	4,276	10	71	14	10,982	27	28,851	75	87,786	25	8,292	10	5,603	3	2,296	21	12,873	13	2,767	41	42,431	20	42,446	12	5,114	890	1,218,160	1895
1896	696	1,159,751	36	8,394	5	2,730	9	6,246	14	11,814	41	44,565	63	103,295	28	12,405	10	6,779	26	7,849	17	12,059	14	4,405	112	77,964	32	106,211	10	3,415	1,113	1,567,882	1896
1897	591	952,486	36	10,489	4	1,942	6	6,601	13	13,539	39	49,341	84	139,728	42	20,351	8	12,910	22	6,740	25	17,248	14	6,984	63	34,076	21	52,769	22	6,727	990	1,331,924	1897
1898	761	1,367,570	65	22,664	5	2,357	9	5,432	17	12,703	48	67,160	104	153,147	27	19,468	19	26,530	9	11,424	29	22,670	12	4,385	141	110,186	21	63,064	23	4,583	1,290	1,893,343	1898
1899	726	1,416,791	31	6,475	3	1,989	8	9,248	30	26,613	51	89,794	93	211,684	50	34,394	31	49,472	3	6,775	34	27,853	29	10,367	127	146,108	21	78,170	32	6,015	1,269	2,121,738	1899
1900	692	1,442,471	38	6,967	2	2,598	12	14,889	17	11,060	66	116,858	93	204,731	61	45,074	36	67,522	3	4,543	42	32,751	19	5,735	196	190,962	39	142,565	48	15,439	1,364	2,304,163	1900
1901	639	1,524,739	68	16,610	6	11,524	7	20,013	41	22,856	92	177,543	101	217,593	33	29,927	35	60,526	94	37,208	40	36,875	31	8,241	234	268,091	52	165,144	65	20,649	1,538	2,617,539	1901
1902	694	1,427,558	65	18,235	4	10,584	16	15,192	44	27,148	99	192,196	108	213,961	114	69,101	62	46,270	53	27,181	46	37,878	32	9,030	206	223,360	45	155,814	62	29,247	1,650	2,502,755	1902
1903	697	1,190,618	64	20,866	9	13,824	6	11,328	39	28,609	75	92,768	120	184,494	109	59,174	81	50,089	62	34,514	54	41,599	30	11,855	195	211,219	51	170,601	58	24,073	1,650	2,145,631	1903
1904	712	1,205,162	55	27,253	6	8,712	40	16,645	30	15,859	69	81,245	149	202,197	109	55,636	35	30,016	67	32,969	67	50,469	32	10,267	208	189,430	19	49,088	45	17,987	1,643	1,987,935	1904
1905	795	1,623,168		45 —	10,798		27	16,402	19	17,557	43	73,124	148	255,423	58	44,135	46	61,629	81	31,725	58	52,580	20	5,282	157	107,368	43	195,459	36	20,272	1,576	2,514,922	1905
1906	886	1,828,343	50	16,026	7	10,016	25	18,590	18	24,712	48	35,214	205	318,230	89	66 809	30	30,560	107	42,489	69	60,774	23	11,579	192	169,358	50	271,729	37	15,334	1,836	2,919,763	1906
1907	841	1,607,890	83	21,479	14	24,964	7	8,717	29	28,819	50	61,635	188	275,003	60	68,623	31	44,666	78	66,254	82	57,556	28	11,781	208	217,530	47	257,145	42	26,026	1,788	2,778,088	1907
1908	533	929,669	111	25,512	8	8,669	24	23,502	24	19,172	50	83,429	120	207,777	76	58,604	34	26,864	73	59,725	81	52,839	23	9,546	202	158,645	36	145,898	20	23,435	1,405	1,833,286	1908
1909	526	991,066	35	6,592	3	869	15	25,006	11	7,508	51	42,197	84	128,696	52	59,106	28	31,217	75	52,319	45	28,601	12	6,316	73	80,485	29	129,119	24	12,900	1,063	1,602,057	1909
1910	500	1,143,169	53	14,601	7	11,742	8	14,304	18	12,154	55	80,751	117	159,303	105	70,945	21	23,019	70	30,215	64	36,931	17	8,904	156	177,601	39	153,717	47	20,497	1,277	1,957,853	1910
1911	772	1,803,844	59	16,006	3	3,656	16	37,836	18	18,689	79	125,472	154	255,532	113	93,050	14	17,401	109	44,359	71	35,435	11	9,427	112	95,693	30	75,876	38	17,864	1,599	2,650,140	1911
1912	712	1,738,514	76	25,090	8	9,700	12	38,821	22	26,103	80	110,734	165	375,317	112	99,439	27	25,196	168	57,755	89	50,255	22	13,968	144	194,273	30	89,950	52	46,654	1,719	2,901,769	1912
1913	688	1,932,153	77	26,744	14	21,595	17	61,757	31	40,932	89	176,095	162	465,226	95	104,296	38	50,356	152	64,664	74	50,837	25	18,524	182	224,232	23	48,216	83	43,455	1,750	3,332,882	1913
1914	656	1,683,553	58	22,288	22	25,246	11	34,335*	25	32,815	33	114,052	89	337,192*	130	118,153	47	42,981	32	85,861	61	54,204	26	15,163	84	162,937	10	37,825	35	36,148*	1,319	2,852,753*	1914
1915	327	650,919	27	13,289	4	8,725	No	Returns	23	45,198	6	25,402	No.	Returns	120	113,075	30	22,132	26	49,408	59	62,070	27	20,319	76	157,167	8	20,293	10	13,641*	743	1,201,638*	1915
1916	306	608,235	36	22,577	4	8,994	No	Returns	28	35,277	9	42,752	No	Returns	201	180,197	10	56,654	55	145,624	52	42,458	34	26,769	167	384,899	44	119,348	18	14,296*	964	1,688,080*	1916
1917	286	1,162,896	80	66,475	25	27,996	No	Returns	23	20,445	6	18,828	No	Returns	146	148,779	11	38,906	104	350,141	44	46,103	34	26,760	266	821,115	60	176,804	27	32,538*	1,112	2,937,786*	1917
1918	301	1,348,120	184	230,514	22	49,390	No	Returns	13	26,150	3	13,715	No	Returns	74	74,026	15	60,791	198	489,924	51	47,723	36	39,583	741	2 602,153	188	430,877	40	34,478*	1,866	5,447,444*	1918
1919	612	1,620,442	235	298.495	28	60,233	—	—	46	37,766	34	32,663	*	*	100	137,086	32	82,713	133	611,883	82	57,578	53	50,971	852	3,579,826	199	495,559	77	79,334	2,483	7,144,549*	1919

* Returns not complete.

Nearly all the vessels launched in this country during the year are for British owners, only 29 ships, totalling 97,459 tons (6 per cent.) having been built for owners of other nationalities. For the five years immediately preceding the war the average tonnage built in this country for foreign owners amounted to over 22 per cent. of the total.

The most notable British vessels launched during the year are the Arundel Castle (22,150 tons), the Cameronia (16,000 tons), the Oropesa (14,000 tons) and the San Fernando (13,056 tons). Of the remainder 127 were between 5,000 tons and 6,000 tons, 47 between 6,000 tons and 8,000 tons, and 11 between 8,000 tons and 10,000 tons. It is a remarkable fact that not a single sailing vessel has been launched in this country during the year, and only 17, with a total tonnage of 148,188, are fitted with turbine machinery. The four largest vessels, above mentioned, are all propelled by means of geared turbines, and five ships, making 32,936 tons together, are provided with Diesel engines; the largest motor ship is a vessel of 6,980 tons.

From the figures given in Table I, which shows the distribution of the work among the different shipbuilding centres of the United Kingdom for the last three years, it will be seen that the Clyde, including Glasgow and Greenock, accounts for 525,747 tons, which is over 32 per cent. of the whole British production. Glasgow yards show an increased production of nearly 80 per cent., as compared with that for the previous year. Next in order of magnitude of production comes Sunderland with 274,283 tons, which is a slight improvement on the figure for the previous year, while Newcastle follows with 239,836 tons, or rather less than the production for 1918. In the case of Belfast and Londonderry, which takes fourth place in the list, the tonnage launched amounts to 213,720, which is an increase of over 42 per cent. on the figure for 1918. The only other district with more than 100,000 tons to its credit is Middlesbrough, Stockton and Whitby, for which the figure is 119,943 tons, or nearly 10 per cent. more than in the previous year.

Other Countries.—Table II gives the number and tonnage of vessels launched by all the shipbuilding countries of the world, from 1892 to 1919 inclusive, except that the figures for enemy countries are not available for the period of the war. Excluding these countries it appears that 1871 merchant vessels, making 5,524,107 tons in all, have been launched outside the United Kingdom. These figures include 1,554 steamers and motor ships with an aggregate tonnage of 5,203,712, and 317 sailing vessels and barges, making 320,395 tons together. It need hardly be mentioned that the foreign-built tonnage is the largest ever recorded, being actually 1,424,783 tons in excess of the 1918 record, and nearly four times as great as the pre-war record of 1,400,729 tons reached in 1913. Most of the foreign-built tonnage is, of course, constructed of steel, but the world shortage of this material is indicated by the fact that 621 ships, making 721,046 tons together, have been built of timber, and 10 vessels with an aggregate tonnage of 20,455 have been constructed of reinforced concrete. Most of the timber construction has been carried on in the United States, which accounts for practically three-fourths of the total wood tonnage built abroad.

United States.—The United States still retains the first position in the world of shipbuilding, having produced 1,051 ships with an aggregate tonnage of 4,075,385 during the year as compared with 929 ships and 3,033,030 tons in the previous year; the increase for the year is thus 1,042,355 tons, or upwards of 34 per cent. The remarkable development of the United States shipbuilding industry is instanced by the fact that the output for 1919 amounts to about 57 per cent. of the world's total, whereas in 1913 the proportion was just over 14 per cent. This development, however, is hardly likely to continue; in fact, at the end of the year the tonnage building in British yards was slightly greater than that in hand in the United States. The vessels launched include 1,900,000 tons propelled by steam turbines, and 43,000 tons fitted with internal combustion engines. Of the latter class 12 ships are between 2,000 tons and 3,000 tons, and one has a tonnage of 6,099. For the transport of oil in bulk 60 steamers, making, together, about 370,000 tons, were launched during the year, and 49 of these vessels, with an aggregate tonnage of 326,000, were constructed on the Isherwood system; 115 other vessels, aggregating about 714,000 tons, were also built on this system. The United States tonnage launched includes three turbine steamers of about 15,000 tons each, built by the New York Shipbuilding Corporation at Camden, N.J., and two turbine steamers of 10,798 tons each, built by the Bethlehem Shipbuilding Corporation at Quincy, Mass. Of the remaining vessels 251 are between 6,000 tons and 10,000 tons, and 137 are between 5,000 tons and 6,000 tons.

Japan.—A remarkable increase in the shipbuilding industry of Japan has taken place during the last four years, so that this country now takes third place among the shipbuilding nations of the world. The tonnage of 611,883 launched in 1919 is 25 per cent. greater than that for the previous year, and almost 10 times as much as was launched in 1913. The 1919 tonnage launched amounts to well over 8 per cent. of the world's total, and to over 11 per cent. of the tonnage built abroad, so that Japan is rapidly becoming an important factor in the shipbuilding world. The figures given refer to steel steamers only, and comprise 48 vessels of between 5,000 tons and 6,000 tons, and 22 ranging from 6,000 tons to 8,230 tons, the largest vessel being the Bangkok, built at Uraga for French owners. It is interesting to note that 14 steamers, of over 5,000 tons each, were launched in Japan during the year for the United States Shipping Board.

British Dominions.—In the British Dominions 263 vessels, making 358,728 tons together, have been launched during the year, and of this total tonnage 271,264 tons are accounted for by Canada. Of the Canadian total 28 steel steamers, with an aggregate tonnage of 60,233, were launched from yards on the Great Lakes. The coast shipyards, and the yards on the St. Lawrence, account for 12 steel steamers of between 5,000 tons and 6,000 tons, and 80 wood steamers, of which 51 are between 1,000 tons and 1,200 tons, and 6 between 2,000 tons and 2,700 tons. The tonnage launched by other British Dominions amounts to 87,464, and more than half of this is due to Hong Kong, where 8 vessels, ranging from 5,000 tons to 5,806 tons each, have been launched during the year. The total tonnage for all the Dominions, it may be remarked, has shown a very considerable expansion during the year, being 78,824 tons greater than the total for 1918, and being practically equal to the entire production for the decennial period ended 1917.

Holland.—The tonnage launched from Dutch shipyards during the year amounts to 137,086, made up by 100 vessels. Although nearly double the tonnage launched in the previous year, the 1919 tonnage is less than the record reached in 1916, for which year the production was 180,197 tons. The highest tonnage launched in any year before the war was that for 1913, which was 104,296, so that the figure for 1919 shows an increase of over 31 per cent. over the pre-war record year.

Italy.—The figures for Italy, which are 32 vessels launched with a total tonnage of 82,713, include, for the first time, the output of Trieste, at which port

23,513 tons have been launched during the year. The total includes 9 steamers of between 5,000 tons and 6,000 tons each, and 3 larger vessels, of which the largest was the Monte Grappa, of 8,500 tons, launched at Trieste. If we subtract the output of the Trieste yards, the remaining 59,200 tons produced in other Italian yards does not differ materially from the tonnage launched in the previous year. For Italy's pre-war record we have to go back as far as 1900, in which year 67,522 tons were launched, so that excluding Trieste the 1919 tonnage is 12 per cent. less than this figure.

Norway, Sweden and Denmark.—The Scandinavian countries between them have launched 181 vessels, making 146,315 tons in all, to which total Norway has contributed 82 ships, with an aggregate tonnage of 57,578. Norway's tonnage is some 10,000 tons greater than that for the previous year, but does not equal the pre-war record of that country of 60,774 tons, reached in 1906. Sweden, on the other hand, has greatly developed her shipbuilding industry during the war, the tonnage launched annually showing a steady increase over the whole war period. The 1919 tonnage launched was 50,971 (53 ships) and this tonnage is something like three times as great as that for 1913. Three vessels of over 4,000 tons each were launched in Sweden last year. The figures for Denmark show an improvement of over 11,000 tons in comparison with those for the previous year, the 1919 tonnage launched being 37,766 (46 vessels), but this tonnage is more than 3,000 tons less than that for 1913. It is interesting to note that the Danish production for 1919 includes the motor ship Afrika, which has a displacement of 9,050 tons, and is the largest vessel fitted with Diesel engines launched in the world.

France and Spain.—The effect of the war on the French shipbuilding industry is well shown by the figures given for that country in Table II. The 1919 tonnage, which amounted to 32,663 (34 ships), certainly shows some improvement on the two previous years, but is not much more than one-sixth of the tonnage launched in 1913. The figures for Spain (which are included in the table under the heading of "Other Countries"), show an increase of more than 35,000 tons over those for the previous year, the tonnage launched in 1919 having been 52,609. This total includes the Arno Mendi, of about 5,700 tons, building at Bilbao.

Conclusion.—The total output for the world during 1919, which was given in the early part of this article as 7,144,549 tons, is considerably higher than ever reached before. It is 1,697,105 tons (over 31 per cent.) more than the tonnage launched last year, and more than twice as much as was launched in 1913, the pre-war record shipbuilding year. Of the total 1919 tonnage, no less than 4,428,540 tons (*i.e.*, about 62 per cent.) are intended for classification in Lloyd's Register Book, and if we consider only the tonnage of steel steamers launched in the world, it appears that 65 per cent. of such tonnage has been built under the Society's inspection. It may be interesting to add, in conclusion, that during the last fifteen years some 26,000,000 tons of shipping has been built under Lloyd's supervision.

RAILWAY ACCIDENT AT CREWE.—Major G. L. Hall's report on the accident which occurred at Crewe on November 17, to a London and North-Western train arriving from Chester, places all blame on the driver of the engine. It appears that this man, on his own evidence, failed to make sure that signals lowered as he approached the signal bridge, were really those which applied to his train, and failed to realise that his train was taking the wrong road, until it was too late for him to avoid running into the stops of the bay into which his train had been turned. The driver, who had a record of nineteen years service in that grade, frankly admitted his error.

PERSONAL.—On and after the 31st inst., the address of the Institution of Petroleum Technologists will be 5, John-street, Adelphi, Strand, W.C. 2.—Alloy Welding Processes, Limited, 14 to 16, Cockspur-street, S.W. 1, state that "A.W.P." electrodes have been approved by "Lloyd's Register of Shipping," and also the British Corporation for the Survey and Registry of Shipping.—The Board of Trade announce that the Scientific Instruments, Glassware and Potash Production Branch and the Mineral Resources Development Department, have removed from 7, Seamore-place, Curzon-street, W. 1, to the new Public Offices, Great George-street, S.W. 1 (Telephone No. Victoria 9800). The office of the Controller of Trading Accounts has also removed to Great George-street from Gwydyr House Annexe, Whitehall, S.W. 1.—The London offices of Messrs. Marshall, Sons and Co., Limited, Gainsborough, will be 3, London Wall Buildings (2nd Floor), London, E.C. 2, on and from next Monday.—The Stanton Ironworks Company, Limited, near Nottingham, have entered into an arrangement under which they purchase, as from January 1 last, the ironworks, foundries and ironstone properties of Messrs. James Oakes and Co., excluding, however, the collieries and the clay works.—Messrs. Thermit, Limited, who have sent us a copy of their pocket-book, state that their offices are now at 155, Church-road, Battersea, London, S.W. 11. The works remain at 675, Commercial-road, London, E. 14.

THE COMMERCIAL SUPPLY OF OXYGEN.

TO THE EDITOR OF ENGINEERING.

SIR,—In the recently-issued report of the Nitrogen Products Committee, certain statements are made on pages 57 and 58, obviously intended to reflect on this company. As these statements are entirely inaccurate and calculated to mislead many people, I shall esteem it a favour if you will afford me space to make the necessary corrections.

I will deal with the points seriatim :—

1. The report says that "it appears from information at the disposal of the committee that the recovery and utilisation of by-product oxygen from nitrogen plants has been checked by restrictive clauses in trade agreements."

There are not, as yet, any nitrogen plants installed in this country, and the only order for such a plant was entrusted to us. It consisted of three large units of the liquid-air type, destined for the committee's belated and unfortunate adventure at Billingham. In the contract there is no mention of any restriction on the use of the oxygen residual. None was ever suggested or contemplated by us. Even a royalty, to which we might have been legally entitled, was not asked for, and the contract for the plant was accepted on a basis of 10 per cent. profit on cost, a profit which we need hardly say is never likely to be realised.

2. The report states that "the oxygen and liquid air industries in this country cannot be said to have enjoyed a free and unrestricted development on a competitive basis, and the prices hitherto prevailing for the compressed and liquid products have not been conducive to their employment to the fullest extent."

This company, established thirty-four years ago, was the first successful commercial enterprise in oxygen, and may justly claim to have founded the world's present industry in that gas. Competition has frequently been experienced by the company in the course of its development, and will, no doubt, be experienced again. Whether that will lead to a freer and less restricted development than hitherto, is a matter for competent consideration in the light of the following facts :—

Oxygen is a supply business analogous to electricity and coal gas. For cheap distribution it has to be produced locally whenever the demand is sufficient to yield an adequate return on the capital involved. This company has steadily pursued that policy. We have to-day oxygen factories in all important industrial centres throughout the country—11 in operation, and others in hand. I believe that no country is better supplied with oxygen factories than England. I know, at any rate, that in France and the United States of America, where competition—that wonderful official panacea for all trouble—prevails to a marked degree, the selling price of oxygen is higher than it is here. Only a few weeks ago I had a visit from an American engineer, prominent in oxygen affairs in the United States. This gentleman admitted that he had arrived in England some weeks earlier with the object of developing an oxygen business. He had personally investigated the situation in all our important industrial centres, and he candidly stated that, as a result, he had found, to his surprise, that the price of oxygen prevailing in this country was so much lower than in America, that he saw no chance of profitably intervening in the business. Before he left he proposed an arrangement under which we should manufacture his company's apparatus for sale in this country. I have reason to believe that this gentleman's visit to England was largely due to the ill-informed reports on the British industry made by a British Government official who visited America during the war.

3. The report states that "prior to the war the selling price of oxygen to fairly large users, inclusive of the cost of compression into cylinders, of hire of the latter, and of freight was of the order of 1*d.* per cubic foot, or, say, 4*l.* per 1,000 cub. ft."

It is to be hoped that this statement is not a fair specimen of the general degree of accuracy throughout the report. Prior to the war the average selling price of oxygen in this country was considerably less than half the figure quoted. This average includes not only industrial supplies in large quantities, but also the gas supplied in small cylinders for medical and entertainment purposes. No charge is made for the hire of cylinders for periods varying from a fortnight to a month, but afterwards a small rent charge is made in order to prevent their unreasonable detention. The average cost of transport is only a few shillings per 1,000 cub. ft. For the year ended March 31, 1919 (the last audited record), the average increase on pre-war figures in the cost of producing, compressing and handling 1,000 cub. ft. of oxygen was 8*s.* 6*d.*, whilst the average increase in the selling price was less than half that amount. I think even Government officials must admit that there is not much evidence of profiteering in these facts.

4. The report states that "Attempts have been made in this country by lamp-makers (electric) to induce the liquid-air industry to take up the commercial manufacture of argon, but so far without success."

There is not a vestige of truth in this statement. This company has expended many thousands of pounds in connection with the production of argon. Prior to the war we had conducted considerable experimental work, and an argon producing plant was in hand when war broke out. Owing partly to war pressure, and the paramount necessity for giving precedence to oxygen supplies, but owing even more to the absence of reasonable assistance from the Government in the matter of labour and material, our first plant was only started shortly after the armistice. It has been in operation, as required, ever since, and a second plant is now being erected in another works. Our difficulty, however, is to find a market for the gas.

I may add that, in addition to the above extracts, there are further statements in this report relating to oxygen and other gases from which we entirely disagree, but, as these are put forward as expressions of opinion rather than fact, I will not trespass on your space with further criticism.

I desire, however, to add in conclusion that there is no shortage of oxygen production in this country. The trouble lies in the distribution of the gas, and this is due entirely to the fact that the manufacture of oxygen cylinders was virtually stopped by the Government during the war. This official action was adopted to enable vast quantities of hydrogen cylinders to be manufactured for airship developments which never materialised. Thousands of these cylinders are now lying unused and deteriorating in air dumps throughout the country, whilst oxygen supplies are being starved, and work of national importance retarded for lack of cylinders. This matter might well be investigated by some competent and independent engineer of recognised authority on behalf of the Government. It would afford this company gratification to have a similar investigation made regarding the oxygen position before, during and since the war. I venture to predict that it would bring to light a striking example of the harm which can be effected by ignorant and prejudiced official interference with a well-conducted, highly technical and responsible industry. It would, I think, also disclose the true source of misleading statements, such as those referred to in this letter.

Yours truly,
K. S. MURRAY,
Managing Director.

THE BRITISH OXYGEN COMPANY, LIMITED.
Elverton-street, Westminster, S.W. 1,
January 27, 1920.

LABOUR UNREST.

TO THE EDITOR OF ENGINEERING.

SIR,—For the past three years the state of unrest amongst the workers has been increasing in magnitude. Various causes are assigned to it by those well-meaning people who are styled "guides and interpreters of public opinion." For remedies, everything is advocated from the abolition of the Coalition to the establishment of a Soviet Republic. In the remedial direction it would seem that the possibilities of error are inexhaustible.

Trades unionism has not brought prosperity or contentment to the workers; nor has federation given the employers peace or security.

Take the ironmoulders' strike, for example. The men have inflicted upon themselves a burden which will take several years to undo; and they have done almost irreparable damage to the industry of the country. The workers who are not employers are like children, and the one thing they require is a maister. The maister is a man who is a father to them, who finds them work and wages, thinks for them, guides them and is their friend.

Limited liability has many things to answer for, and one of these is the "want o' maisters," as the poet Burns terms it. The men of limited liability must learn that when they pocket their dividends they have taken the maister's share and have left the maister's work undone.

When a mother suddenly dies and leaves her numerous offspring without their natural caretaker, there is dismay in the home. When there is confusion amongst the workers such as there is to-day it shows that they have no guide or friend.

The President of the Friendly Society of Ironfounders is, I believe, the Right Hon. Arthur Henderson, P.C., M.P., who, in his early life, practised as an ironfounder, but who never became a maister, but instead became a local preacher and a Liberal agent. He was a paid servant of the Liberal Party when he was elected Labour Member of Parliament for Barnard Castle.

Now, I ask, how is a country or its industries going to progress if the maisters are nae maisters; and the men's leaders think it a wise thing to get a living as a Liberal agent, and combine with this a delegate to the Socialist International and Chairman of the Labour Party and a local preacher of Christianity? In the name of sacred truth, how can the workers be in any other condition but "confusion worse confounded," when they are guided (*sic*) by leaders who are themselves in a state of confusion?

If the limited liability men will not do their share of the work which stands so much in need of doing, then let them frankly do what the Parliament of Notables did when they addressed the "most invincible of sovereigns": "We have failed to govern; govern thou in thine own name."

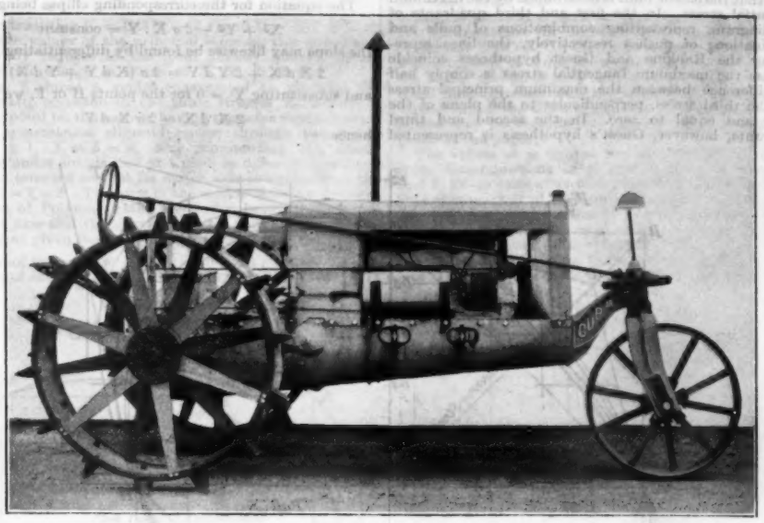
Your obedient servant,
MALCOLM MACPHERSON.

10, Albemarle-street, E.C. 1.

BRITISH INDUSTRIAL "SAFETY FIRST" ASSOCIATION.—This association, whose offices are 2 and 3, The Sanctuary, Westminster, S.W. 1, has issued Technical Pamphlet No. 1, for December last, which contains a detailed article on good lighting as an aid to safety, illustrated by numerous views and diagrams.

PERMANENT INTERNATIONAL WORLD'S MART, PARIS.—It is the intention of the Association of Great Britain and France, whose offices are 123, Victoria-street, S.W., to hold a public meeting at Princes Restaurant, at 3 p.m. on Tuesday, February 3, when Monsieur Julien Bessonneau, the President of the Conseil d'Administration of the Paris Marché du Monde, and the Marquis de Breviaire, will be present to explain the great scheme for a permanent International World's Mart in Paris.

WALLIS JUNIOR 4-CYLINDER AGRICULTURE TRACTOR.



As of interest in connection with the Lincoln tractor trials, the results of which we dealt with in our issue of the 16th inst., we give an illustration on this page of the Wallis Junior tractor. This was one of the few entrants which we were not able to illustrate in connection with our original article on the trials, which appeared in our issue of October 3 last. The Wallis Junior, as will be seen from our figure, is of the type having a single front road wheel; in this differing from the majority of entrants; the double front wheel arrangement being much more common. The tractor is also unusual in the construction of the body, which is built up of boiler plate in the form of a trough. This trough forms the crank-case of the engine, and also houses the gearing so that a very adequate protection of the vital moving parts is attained, while at the same time weight is saved as compared with the more usual type of frame construction.

The tractor is fitted with a four-cylinder monobloc engine. The cylinders are 4¼ in. bore by 5½ in. stroke, and have removable sleeves. The crankshaft is 2½ in. diameter, and is carried in three main bearings. Lubrication is by automatic circulation and splash, and ignition is from a high-tension magneto. A Halliday paraffin carburettor is fitted. The normal speed of the engine is 900 r.p.m. A governor is provided. The clutch is of the expanding shoe type and the gearing, of the sliding type, gives speeds of 2½ miles and 4 miles per hour forward and one reverse. The gears run in an oil bath and, as will be realised, the generating unit and transmission are in general on motor-car lines. The gear box and differential are fitted throughout with Hyatt roller bearings. A belt pulley for machinery driving is fitted. It is 18 in. in diameter, and runs at 430 r.p.m. It is controlled through the main motor clutch.

The driving wheels of the tractor are 48 in. diameter, with a 12 in. face. The single front wheel is 30 in. diameter, with an 8 in. face. It is spring mounted, as is clearly shown in the figure. The overall dimensions of the machine are: Length, 11 ft. 7 in.; width, 5 ft.; height, 5 ft. 4 in. The wheel base is 8 ft. 4 in. It is claimed that the tractor will turn within a radius of its own wheel base. The total weight is 3,360 lb., and a constant draw-bar pull of 2,000 lb. is claimed. It will be seen from the table published in our issue of the 16th inst., that at Lincoln a pull of 2,600 lb. was necessary to skid the tractor wheel, and that a sustained pull of 2,800 lb. was attained at ploughing speed. The agents for the tractor in this country are The Ancona Motor Company, Limited, of 78 to 82 Brompton Road, London, S.W. 3.

SWEDISH MANUFACTURE OF SYNTHETIC NITROGEN.—According to *Swedish Export*, the Swedish company called Kväveindustri, which has for a considerable time been carrying on experiments for the production of synthetic nitrogen by a method thought out by the Swedish engineer Thorsell, has now begun manufacture on a large scale. The company's output is placed on the market in the form of ammonium sulphate. According to a statement emanating from the directors of the company, the method will be well able to face competition, as the costs of production are extremely low.

BRINELL MACHINE FOR HIGH-TEMPERATURE TESTING.

AT the meeting of the Institution of Mechanical Engineers held on December 19 last, for the consideration of Mr. Burley's paper on the "Cutting Power of Lathe Turning Tools," the question of the relation between the cutting efficiency of tools and their Brinell hardness number at high temperatures was raised

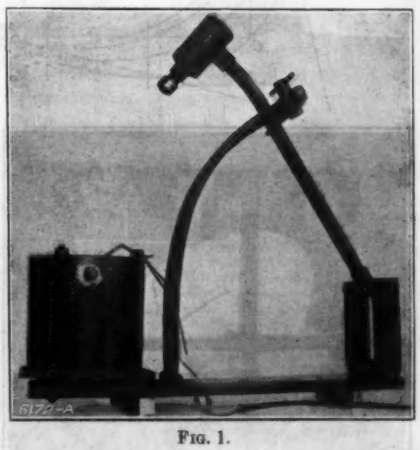


FIG. 1.

by Mr. J. F. Kayser, of the Spartan Steel Company, Limited, of Carlisle Street, Sheffield. A report of Mr. Kayser's remarks at the meeting will be found in our issue of December 26 last. We are now able to give further particulars of Mr. Kayser's methods, and to illustrate the machine which he used. The machine, which is illustrated in Fig. 1 on this page, will be understood from what we have said above to be constructed for the purpose of determining the Brinell hardness of metal specimens at high temperatures. The design of the machine is such that the specimen is not removed from the heating chamber during the test, and the cooling effect of the ball upon the specimen is negligible. The energy of the blow also does not enter into the short calculation necessary for obtaining the final hardness number.

The details of the machine will best be followed from Fig. 2. The specimen to be tested is placed on a metal anvil, which is surrounded by a silica heating tube wound with Ni-Cr. wire, which carries an electric current. The heating tube is sufficiently long to ensure that the whole of the specimen and the top of the anvil can be maintained at a uniform temperature. A thermo-couple is fitted for measuring the temperature, a hole being drilled in the specimen for receiving the hot junction. When hardness determinations are required at temperatures above about 500° Cent., it is usual to pass an inert gas into the heating tube in order to prevent the formation of scale. When the specimen has reached the required temperature a weight is allowed to fall into the heating tube. The striking face of this weight carries a hardened steel ball, behind which is a comparison piece of metal, the Brinell hardness of which has been previously determined. The ball and comparison piece are held in contact, and hence the specimen under test and the comparison piece each receive the same blow, and an impression is formed upon each. If c is the spherical area of the impression formed on the comparison piece and h the spherical area of the impression formed on the heated specimen, then:—

$$\left.\begin{array}{l}\text{Brinell hardness of}\\ \text{heated specimen}\end{array}\right\} = \left\{\begin{array}{l}\text{Brinell hardness of com-}\\ \text{parison piece} \times \frac{c}{h}.\end{array}\right.$$

It is desirable that the Brinell hardness of the comparison piece should be approximately the same as that of the specimen being tested. In measuring up the diameter of the impression from which the spherical area is calculated from the heated specimen, it is not necessary to make a correction for the contraction of the specimen during cooling, as the effect is so small.

The investigations of Dr. Arnold showed no connection between the cutting efficiency and the Brinell hardness of cutting tools. With the apparatus we are dealing with it has been found that if Brinell hardness determinations are made at different temperature up to about 750° Cent., the results obtained can be correlated with the cutting results obtained in the lathe. An examination of the hardness curves of different steels shows that the greater the cutting efficiency the higher is the Brinell hardness at elevated temperatures. The two curves in Fig. 3 illustrate the variation of Brinell hardness with temperature for two modern high-speed steels. Curve a is for a

Fig. 2.

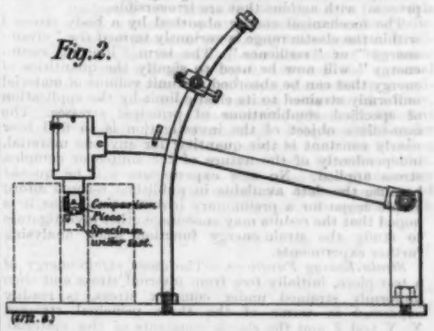
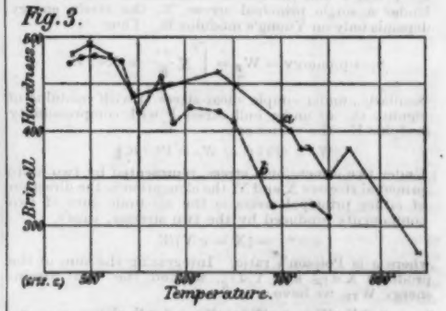


Fig. 3.



chromium-molybdenum-cobalt high-speed steel, and curve b for a special 18 per cent. high-speed steel containing tungsten, chromium, molybdenum (1 per cent.) and vanadium (1 per cent.). We are indebted to Mr. Kayser for the information and illustrations on which this brief description of his machine is based.

AFRICAN OIL CORPORATION.—The secretary of the African Oil Corporation, Limited, states, according to *The South African Mining and Engineering Journal*, that the following are the salient features of the consulting engineer's report, dated November 18, 1919: Work was commenced on the company's properties early in September and has been pushed ahead with considerable energy. The shale has been proved for a distance of 3 miles by means of extensive cuttings into the hillside. The cuttings for the most part disclose a complete section of the shale of an average width of 5 ft. Assays made from the various faces exposed in the cuttings give an average value of 30 gallons of oil per ton over a retorting width of 4 ft., the allowance in wastage in mining being estimated at 20 per cent. This value is equivalent to 60*s.* per ton on the basis of pre-war selling prices, and should show a profit of 35*s.* per ton without any allowance being made for the much higher prices obtaining at present. The prospecting operations disclose the existence of a much larger area of oil shale than was originally assumed to exist. A survey with a view of deciding the plan of permanent development is about to be made.

THE STRAIN-ENERGY FUNCTION AND THE ELASTIC LIMIT.

By B. P. HAIGH, M.B.E., D.Sc.

Introduction.—The elastic limit of a ductile metal is usually defined as that limiting intensity of stress beyond which permanent strain is first produced; or alternatively, beyond which stress and strain are no longer proportional. The same definition may be adopted for complex stresses, the intensities of all three principal stresses being then required to specify the elastic limit.

Several hypotheses, based on direct experiment and empirical in nature, have been advanced with the object of establishing a direct relation between the elastic limits for simple and complex stresses; and certain of these are now in general use, yielding reliable results in particular circumstances. In what follows, reference will be made to three hypotheses—due to Lamé and Rankine, to de Saint Venant and to Tresca, Darwin and Guest. According to different hypotheses, the maximum principal stress or strain, or the maximum tangential stress, or the latter together with internal friction, may be regarded as the criterion of elastic failure.

In studying these alternative hypotheses, it occurred to the author that a more general relation between the elastic limits under simple and complex stresses might be found by directing attention to the energy absorbed by the material in virtue of its elastic strain. This view was based upon thermodynamic considerations; but, in this paper, only the experimental aspect of the question will be discussed. On another occasion the author hopes to deal with the theoretical results obtained by applying the principles of thermodynamics to the current theory of ductile strain; the process of strain being regarded as one in which crystalline metal is converted to the harder vitreous state in a manner that is thermodynamically reversible although associated (like every thermal process) with actions that are irreversible.

The mechanical energy absorbed by a body stressed within the elastic range is variously termed the "strain-energy" or "resilience." The term "limiting strain-energy" will now be used to signify the quantities of energy that can be absorbed per unit volume of material uniformly strained to its elastic limit by the application of specified combinations of principal stresses. The immediate object of the investigation is to find how nearly constant is this quantity, for any one material, independently of the nature of the simple or complex stress applied. No new experiments will be quoted because the data available in published records afford ample scope for a preliminary investigation; but it is hoped that the results may encourage other investigators to study the strain-energy function when analysing further experiments.

Strain-Energy Functions.—The mean strain-energy of a test-piece, initially free from internal stress and then uniformly strained under complex stress, is readily expressed in terms of the three principal stresses, X, Y and Z and the elastic constants of the material. Under a single principal stress, X, the strain energy depends only on Young's modulus E. Thus

$$\text{Strain-energy} = W_x = \int_0^x X \frac{dx}{E} = X^2/2E$$

Similarly, under simple shear-stress Q with modulus of rigidity C or under bulk-stress P with compressibility modulus K—the values are

$$W_q = Q^2/2C \text{ or } W_p = P^2/2K.$$

Under two-dimensional stress, represented by two finite principal stresses X and Y, the elongation in the direction of either principal stress is the algebraic sum of two components produced by the two stresses, thus:

$$e = (X - \sigma Y)/E$$

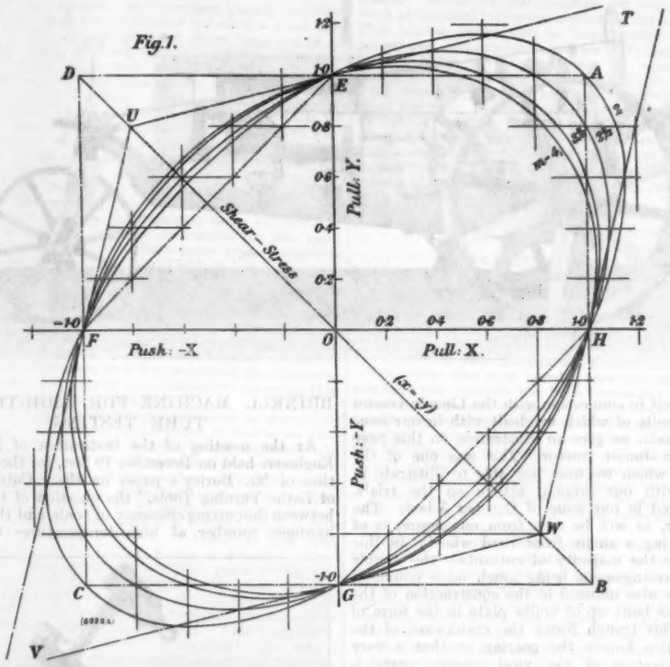
where σ is Poisson's ratio. Integrating the sum of the products $X.de_x$ and $Y.de_y$, to find the total strain-energy W_{xy}, we have:

$$2E.W_{xy} = (X^2 + Y^2 - 2\sigma X.Y)$$

Taking $2E.W_{xy}$ as constant, this quadratic equation expresses the relation between two principal stresses varied in such a manner that the strain-energy W_{xy} is constant. This equation is plotted in Fig. 1 for different values of Poisson's ratio from 0·50 to 0·25 ($m = 1/\sigma = 2, 2\frac{1}{2}, 3\frac{1}{2}$ and 4). The ellipses have been plotted to pass through the points ($X = \pm 1$, $Y = 0$ and $X = 0$, $Y = \pm 1$) representing the elastic limits under simple longitudinal pulls and pushes in different directions. The major and minor axes of the ellipses, at 45 deg. to the axes of X and Y, are as given below:—

Value of m ...	2·0	2·5	3·0	3½	3·5	4·0
Semi-major axis	1·414	1·291	1·25	1·195	1·183	1·153
Semi-minor axis	0·817	0·845	0·867	0·879	0·882	0·895

On the hypothesis that the limiting strain-energy is independent of the nature of the applied stress, these ellipses indicate the variations of the limiting principal stresses for the elastic limit under two-dimensional stress. For example, the elastic limit under simple shear-stress ($X = -Y$) should be somewhat more than half the tensile elastic limit. Also, under combinations of similar principal stresses, *e.g.*, two pulls in perpendicular directions, the elastic limit should be increased by the influence of the second stress when the latter is of moderate intensity; and reduced when the two stresses approach equality. The same diagram shows, also, the conclusions drawn from other hypotheses relating to the elastic limit under complex stress. The square A B C D, drawn with its sides passing through the points $X = \pm 1$, $Y = 0$ and $Y = \pm 1$, $X = 0$, represents Rankine's hypothesis that the elastic limit depends solely on the maximum principal stress—the limits under pull and push being here assumed to be equal. The six-sided figure A H G C F E likewise represents Guest's law—that the elastic limit is determined by the maximum tangential stress. In the first and third quadrants of the diagram, representing combinations of pulls and combinations of pushes respectively, the lines representing the Rankine and Guest hypotheses coincide because the maximum tangential stress is simply half the difference between the maximum principal stress and the third stress, perpendicular to the plane of the paper and equal to zero. In the second and third quadrants, however, Guest's hypothesis is represented



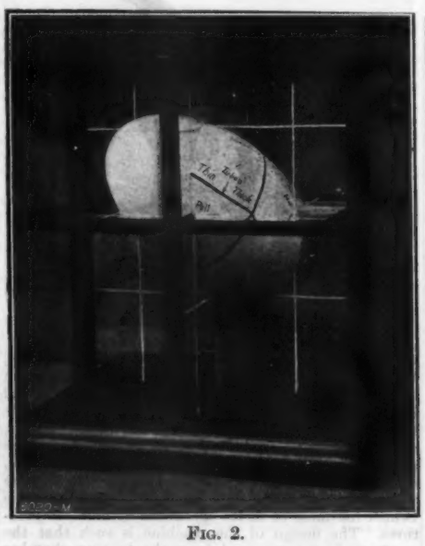


FIG. 2.

by the straight diagonal lines F E and G H, the maximum tangential stress being equal to half the numerical sum of the pull and push stresses acting in perpendicular directions. Parallelograms, *e.g.*, T W V U, represent de Saint Venant's hypothesis that elastic failure occurs only when the maximum principal strain exceeds a definite limit, equal to the limiting elastic elongation under simple pull. These parallelograms, only one of which is shown, vary in form according to the value of Poisson's ratio, and circumscribe the ellipses representing constant limiting strain-energy—the four sides of any parallelogram touching the corresponding ellipse at the four points E, F, G and H.

The latter relation may be proved readily as follows: For the de Saint Venant lines, H T, we have:

$$E.e_y = X - \sigma Y = \text{constant},$$

hence, differentiating,

$$dX - \sigma\, dY = \text{zero}$$

whence it follows that the slope of H T is:

$$\frac{dY}{dX} = \frac{1}{\sigma} = m.$$

The equation for the corresponding ellipse being:

$$X^2 + Y^2 - 2\sigma X.Y = \text{constant}$$

the slope may likewise be found by differentiating

$$2X\,dX + 2Y\,dY = 2\sigma(X\,dY + Y\,dX)$$

and substituting $Y = 0$ for the points H or F, we have:

$$2X\,dX = 2\sigma X\,dY$$

hence

$$\frac{dY}{dX} = \frac{1}{\sigma} = m.$$

Thus the slopes of the ellipses, where they pass through the points H and F, coincide with those of the lines W H T and V F U forming the de Saint Venant parallelograms.

It will be observed that this diagram affords a convenient means of comparing the results of experiment with the indications of the several hypotheses. Sections of the diagram will be used for this purpose in subsequent figures.

For combinations of three finite principal stresses, the total strain-energy may likewise be expressed.

$$2E.W_{xyz} = (X^2 + Y^2 + Z^2) - 2\sigma.(Y.Z + Z.X + X.Y)$$

Other forms of the energy function, based on the three principal stresses and two independent variables expressing the elasticity of isotropic materials, have been given by Lamé (1852); but the above is well known and, probably, the most convenient and fundamental.

For the more general case of non-isotropic crystals, Green (1837) established an expression in which 21 independent variables appear. It is important to observe that the simpler expressions are rigorously applicable only for isotropic materials; and that, being applied to ordinary crystalline metal composed of large numbers of non-isotropic grains with axes oriented in different directions, they give only the mean strain-energy for the gross mass under uniformly applied stress. The quantities of energy absorbed by individual crystalline grains may vary above or below this mean value; and may vary for different parts of individual grains according to the configuration of the boundaries. Evidence of this non-uniformity may be observed by studying the disposition of slip bands within particular grains.

Instead of expressing the strain-energy in terms of the three mutually perpendicular principal stresses, we may adopt the method introduced by Kelvin, and express the state of stress in terms of a single bulk stress P and two mutually perpendicular shear stresses, Q_{xy} and Q_{zy}. The bulk stress is the algebraic mean of the three principal stresses,

$$P = \frac{1}{3}(X + Y + Z)$$

while the two shear stresses are equal to the two smaller of the three residuals obtained by subtracting the bulk stress from the principals. For example, if the residual $(Y - P)$ is numerically greater than $(X - P)$ and $(Z - P)$—being equal and opposite to their sum $(X + Z - 2P)$—the two shear stresses are:

$$Q_{xy} = (X - P) = (2X/3 - Y/3 - Z/3)$$

and

$$Q_{zy} = (Z - P) = (2Z/3 - X/3 - Y/3).$$

In terms of these fundamental stresses, the mean strain-energy is simply the sum of the quantities due to the three independent stresses, viz:—

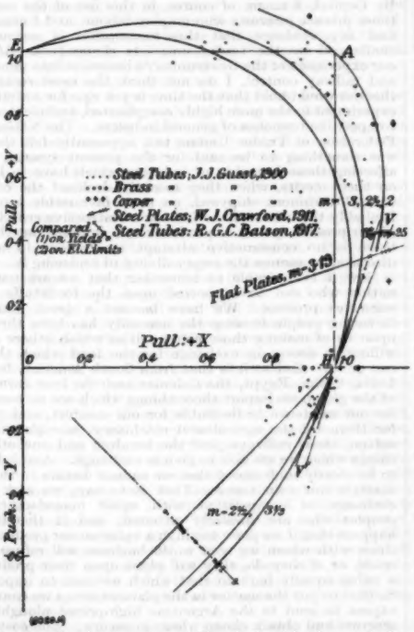
$$W_{xyz} = (P^2/2\,K + Q^2_{xy}/2\,C + Q^2_{xy}/2\,C)$$

On substituting $K = E/3(1-2\sigma)$ and $C = E/2(1+\sigma)$, and the values of the principal stresses, this expression naturally reduces to the form already quoted, giving the strain-energy in terms of X, Y, Z, E and σ.

Fig. 2 shows a model constructed to visualise the quadratic equation in the three stresses X, Y and Z, every point on the surface having the same strain-energy. The symmetrical ellipsoid passes through the points $X = \pm 1$, $Y = Z = 0$, &c., representing the elastic limits under simple pull and push in different directions and is oriented so that its major axis coincides with the line X = Y = Z. The form of the model varies for different values of Poisson's ratio, the ratios between the semi-major axis and the elastic limit for simple pull or push being as given in the following table:—

Value of m	...	2·0	2·5	3·0	3½	3·5	4·0
Value of ratio...		Infinity	2·235	1·732	1·582	1·528	1·414

Fig. 3.



The equal minor axes are identical with those of the ellipses shown in Fig. 1; these ellipses being the traces of the model with the plane of projection, Z = 0.

The lines drawn on the (glass) planes of projection represent the co-ordinates of the elastic limits under simple pull and push. The markings on the surface of the ellipsoid represent particular combinations of stress, *e.g.*, the three-dimensional stresses in thick and thin tubes subjected to internal fluid pressure. The circle drawn round the minor axis is the locus of points representing combinations of shear stresses without bulk stress. Bulk stress alone is represented by the major axis, X = Y = Z.

In the case of an incompressible substance, if such existed, (K = infinity, $m = 2$) the model would become a cylinder with its axis along the line of bulk stress. The same cylindrical model may be regarded as illustrating a modified hypothesis, according to which the strain-energy due to bulk stress, although finite, plays no part in promoting ductile strain.

Analysis of Published Experimental Results.—The following diagrams represent a summary of the results of numerous determinations of the elastic limits of different metals under two and three-dimensional stresses. The diagrams for experiments with two-dimensional or nearly two-dimensional stresses have been drawn up on the following principle: The intensities of the principal stresses, under which permanent strain was observed, have been expressed as ratios to the single principal stress which, acting alone as simple pull, produced permanent elongation. The values of these ratios, X and Y, have been taken as the co-ordinates of the points marked on the diagrams. Thus each point represents a comparison between two experiments, one under complex stress and the other under simple pull. The positions of the points record the stress ratios only, not the absolute values of the stresses. When ascertainable, the elastic limits of the test-pieces have been used as the basis of comparison, but in several instances the yield-points have been compared in the same manner.

The diagrams show also the ellipses representing constant limiting strain-energy, and the figures corresponding to other hypotheses. The positions of the experimental points, relatively to these loci, afford a convenient and direct check on the validity of alternative hypotheses.

Fig. 3 reproduces that part of the two-dimensional stress diagram which relates to pull, X, combined with a perpendicular pull or push, $\pm$ Y. The majority of the experimental points represent Guest's experiments* on steel, brass and copper tubes subjected to combinations of tension and torsion (quadrant X O −Y), or combinations of tension and internal pressure (quadrant X O Y). In the latter experiments, the metal was subjected to three finite principal stresses; but as the radial pressures that constitute the third stress are small in comparison with the tensions produced in thin-walled tubes, the third stress may be neglected; or the points may be regarded as slightly in relief above the plane of the paper.

The values of m quoted for the steel tubes, deduced from determinations of E and C, vary between 2·36 and 3·50—a somewhat wide range; but it is recognised that this method of measuring Poisson's ratio, although convenient and theoretically correct, is liable to give erroneous values when even small errors are present in the determination of the moduli. The values quoted for the brass and copper tubes are respectively 2 to 2·2 and 2·3. Ellipses have been plotted corresponding to $m = 2$, 2·5 and 3½.

Fig. 4.

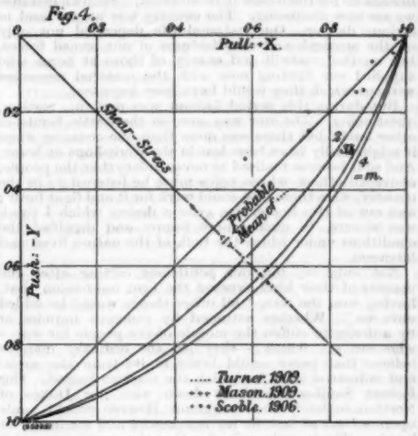
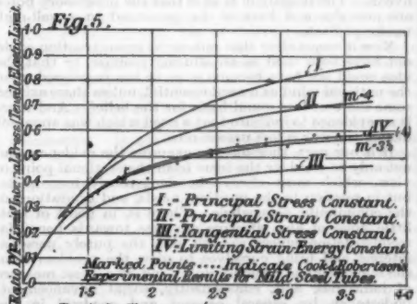


Fig. 5.



Inspection of the diagram indicates that the points approximate to the ellipses, at least as closely as to any of the straight-line loci. The points lie outside the square H A E O where the two stresses are both pulls, but the one substantially greater than the other; and fall within the square near the corner A, where the stresses approach equality. And in the same quadrant X O Y, the change from steel to brass or copper is accompanied by a general movement in the outward direction, as would be anticipated on the assumption that the limiting strain-energy is constant. In the lower quadrant, the points are widely distributed, but generally lie between the lines representing constant maximum principal and tangential stresses, in the region occupied by the ellipses.

The thin steel tubes employed in Guest's experiments being of moderately high tensile material, with elastic-limits under simple tension from 15 tons to 27 tons per square inch., it is inferred that the constant strain-energy hypothesis is reasonably applicable for ordinary steels, although their microstructional features are too complex to admit of any complete theoretical treatment, such as would be required to apply thermodynamic principles.

Fig. 3 shows, also, five experiments by Crawford† on flat steel plates of circular profile, clamped at the edges and subjected to fluid pressure on one side. Crawford concludes that, for such plates, de Saint Venant's hypothesis (represented by the straight lines H V and H V. for $m = 2{\cdot}5$ and 3½) is more applicable than Rankine's hypothesis of constant maximum principal stress. The value of m for these plates, experimentally determined, was 3·19. As de Saint Venant's lines lie, in this part of the diagram, only slightly outside the ellipses which they touch at H, it follows that this and other evidence that supports de Saint Venant's hypothesis may be regarded as giving almost equal support to the hypothesis of constant strain-energy. When the two principal stresses are more nearly equal, as in rotating disc, de Saint Venant's hypothesis overestimates the elastic limit and cannot be regarded as reliable.

Tests by Batson,* on two mild-steel tubes, are also represented in the same diagram. In these tubes, which were tested in torsion and in tension, the ratio between the elastic limits is somewhat different from that between the yield-points. This may have been due to the comparatively thick walls of the tubes, the ratio between the internal and external diameters being 0·72. These results were described as supporting Guest's hypothesis, but are more closely in agreement with the hypothesis of constant limiting strain-energy.

Fig. 4 shows the portion of the diagram relating to combinations of pull and push; particularly with equal intensities, producing simple shear. Three experiments, described in detail by Mason,† are represented by points close to the ellipses; and several other experiments on steel tubes, more briefly mentioned in the same article, give points between the ellipses and the straight line H G. A number of points represent other experiments on steel tubes in torsion and pull, by Turner.‡ The ratio between the two elastic limits varies widely in the different specimens tested; but analysing the observations by the theory of probabilities—as applied in problems of external ballistics—Sears‖ showed that the probable limit of torsion was 6½ per cent. greater than half the elastic limit in tension. Several comparative tests by Scoble§ are also represented in the same diagram. These were carried out on solid unannealed test-pieces subjected to combined bending and torsion, and the yield-points were quoted as the bases of comparison. The limits under combined stress appear unusually low in this series, lying well within the straight line H G.

Experiments with Combinations of Three Finite Principal Stresses.—For combinations of three finite principal stresses, the above method of comparison is less convenient than that adopted by Cook and Robertson¶ in their investigation of the elastic limit of thick-walled tubes subjected to internal fluid-pressure. In this investigation, a number of tubes were tested under gradually increasing pressure, producing hoop-tension, axial-tension and radial pressure in the material of the inner layer. By varying the ratio, k, between the external and internal diameters of the tubes, the relative magnitudes of the three principal stresses were varied widely, affording a direct comparison of the effects of different complex stresses. The elastic limit of the material under simple tension, F, was also measured; and the limiting internal pressure, P, was expressed as a fraction of this. Since the lengths of the tubes were great enough to render the influence of the ends negligible, Lamé's method of calculating the principal stresses could be applied with confidence. These stresses are:—

X = hoop tension = $P(k^2+1) \div (k^2-1)$
Y = axial tension = $P \div (k^2-1)$
Z = radial pressure = P

Cook and Robertson showed that, for each of the current hypotheses, the limiting internal pressure, P, could be expressed in terms of the elastic limit, F; thus:—

On Rankine's hypothesis $P/F = (k^2-1) \div (k^2+1)$
On Guest's hypothesis $P/F = (k^2-1) \div 2k^2$
On de Saint Venant's (with $m = 4$) $P/F = 4(k^2-1) \div (5k^2+2)$.

Fig. 5 shows these expressions plotted, as functions of k, for tubes of different thicknesses. Cook and Robertson's experimental values are also plotted and lie well below graphs I and II, representing the Rankine and St. Venant hypotheses, but above the third graph, III, which represents Guest's hypothesis of constant maximum tangential-stress. The author has added two graphs, IV, giving the values of the ratio, P/F, corresponding to the hypothesis of constant strain-energy; and it is observed that these follow the experimental points very closely.

According to the hypothesis of constant strain-energy the relation between P/F and k is deduced in the following manner, which may be regarded as typical of the methods applicable wherever the ratios between the principal stresses are known. In the general equation for strain-energy

$$W_{xyz} = \frac{1}{2E}(X^2+Y^2+Z^2) - \frac{1}{mE}(YZ+XZ+ZX)$$

substitute the expressions for the principal stresses.

$$W_{xyz} = \frac{P^2}{E(k^2-1)^2} \times \left\{\tfrac{1}{2}[(k^2+1)^2+(k^2-1)^2+1] - \frac{1}{m}[-(k^2-1)-(k^2+1)(k^2-1)+(k^2+1)]\right\}$$

$$= \frac{P^2}{2E(k^2-1)^2}\left[3\left(1-\frac{2}{m}\right)+2k^4\left(1+\frac{1}{m}\right)\right]$$

$$= \frac{P^2}{2(k^2-1)^2}\left[\frac{1}{R}+\frac{k^4}{G}\right].$$

Equating this quantity to the strain-energy in simple tension, $W_f = F^2/2E$, we have

$$\frac{P^2}{F^2} = \frac{(k^2-1)^2}{3(1-2\sigma)+2k^4(1+\sigma)}$$

whence, substituting $m = 1/\sigma = 4$, we have

$$\frac{P}{F} = \frac{2(k^2-1)}{\sqrt{6+10k^4}}.$$

* J. J. Guest, Phys. Society, May 25, 1900.
† W. J. Crawford, Proc. R.S. Edin. (1911–12).

* R. G. C. Batson, Proc. Inst. Mech. Eng., 1917.
† Wm. Mason, *Engineering*, December 24, 1909.
‡ Professor Turner, *Engineering*, February, 1909.
‖ J. E. Sears, *Engineering*, February 19, 1909.
§ W. A. Scoble, *Phil. Mag.*, ii., 1906.
¶ Cook and Robertson, *Engineering*, December 15, 1919.

which expression gives one of the two graphs, IV, plotted in the diagram.

The corresponding graph for $m = 2$, corresponding to the modified hypothesis that ductile strain depends on the energy absorbed through the agency of shear-stresses only, and not on that due to bulk-stress, lies slightly below those actually shown in the diagram. The equation of the graph corresponding to $m = 2$ is

$$P = \frac{(k^2 - 1)}{\sqrt{3}k^2}$$

giving ordinates of $P/F = 0{\cdot}432$ or $0{\cdot}513$ when $k = 2{\cdot}0$ or $3{\cdot}0$ respectively.

The validity of the constant limiting strain-energy hypothesis, as a serviceable approximation to a law that is doubtless more complex, may be inferred not only from scientific investigation of cases, such as the above, that admit of exact calculation and measurement, but also from observation of phenomena that do not admit of exact treatment. The process of wire-drawing is a case in point. In drawing, wire is subjected to three dimensional stresses in the dies, viz., axial tension and two-dimensional compression—a combination which, in the model shown in Fig. 2, is represented by the region at the rear of the upper right-hand quadrant, where the (vertical) tension is comparatively low. Approximate calculations, based on the hypothesis of constant limiting strain-energy, indicate that the pull required to give 7½ per cent. reduction in dies of ordinary proportions should vary from 30 per cent. to 50 per cent. of the tensile strength; whereas, in practice, it is found that the actual pull required seldom reaches half the tensile strength. Although the influence of friction is too uncertain to admit of accurate calculation, the agreement is, at least, within the limits of uncertainty.

It may be noted, also, that strain-energy limits are already used in practice, to a limited extent, in connection with calculations relating to springs. The energy that can be stored per unit volume of solid round wire, wound free in a closely-coiled helical spring, with maximum shear-stress q is $W = (\frac{1}{4}q^2/C)$ where C is the modulus of rigidity. As q varies from about 40,000 to 80,000 lb. per square inch and C is approximately 12,000,000, W runs from 35 in.-lb. to 130 in.-lb. per cubic inch. In a spring required to carry a concentrated load P with an elastic deflection L, the total stored-energy is $(\frac{1}{2}P\ L)$; hence the volume of metal required is simply $(\frac{1}{2}P\ L \div W)$. The hypothesis that the limiting strain-energy per unit volume is the same, in torsion and bending, leads to the conclusion that the helical spring should be capable of storing 50 per cent. more energy than a well-designed coach-spring of equal volume (with constant maximum stress along its many leaves); the expressions for the mean strain-energy being respectively $(\frac{1}{4}q^2/C)$ and $\frac{1}{2}f^2/E)$, which are in the ratio 6 : 4. It may be observed that this conclusion is roughly endorsed by experience of the endurance of such springs under comparable conditions of service.

"MANUAL OF MOTOR MECHANICS."—The full title of this publication is "A Manual of Motor Mechanics and High Efficiency Tuning." It is edited by Mr. L. Mantell, and is published at the price of 3*s.* 6*d.* net by the Temple Press, Limited, 7 to 15, Rosebery-avenue, London, E.C. 1. It contains about 240 pages of detailed illustrated information on the working of internal-combustion engines, their cooling, ignition, lubrication, &c., full particulars being given on every component part. It fully justifies its title in that it is a guide to high efficiency tuning. The present is the fourth edition.

THE MEANING OF F.O.B.—Until a uniform interpretation of the expression F.O.B. is established, the American Chamber in London, says *The Bulletin of the Federation of British Industries*, publishes the parallel meanings prevalent in each country. If buyers and sellers on both sides of the water will study them, or keep them handy for reference, they will always know not only what a quotation from the other country may mean, but also how their own quotations may be interpreted there. When a British merchant quotes "f.o.b.," the accepted definition is: Free on board export vessel, with further charges only to the buyer, the mate's receipt, wharfinger's receipt, or dock receipt issued against the goods being immediately exchangeable for the bills of lading. "F.o.b. port" (New York, Boston, &c.) is upheld both by law and by good practice in the United States to mean the same thing as in Great Britain. It has been found, however, that American shippers, with the best intention, have often misconstrued this as if equivalent to "delivered railway station—port," sometimes leaving to the foreign buyer not only the charges, but even the actual arrangements for the transfer of the goods from the railway station to the vessel. The only infallible remedy is for American sellers to make, and for foreign buyers to insist upon, quotations "f.o.b. export vessel." There is then no opportunity for misunderstandings. "F.o.r." meaning "free on rails" is the term used by British merchants for domestic inland traffic, and corresponds to the American "f.o.b." "F.o.b.," as previously stated, is used extensively in the United States for domestic inland traffic, meaning "free on board railway car at point of origin." The gravity of the present situation is indicated by the National Foreign Trade Council's recent statement strongly urging American exporters and manufacturers to standardise the interpretation of "f.o.b. port" as meaning "f.o.b. export vessel." The Foreign Trade Bulletin of the American Express Company, issued at New York in October, discusses the question with unmistakable finality.

INDUSTRIAL RECONSTRUCTION.*

By ALEX. RAMSAY.

I DO not believe that you have asked me here to-night to discuss the question of Industrial Reconstruction from the point of view of an interested party. I think you would desire me, and it is certainly my intention, to deal with the problem so far as I can from a critical and impartial standpoint, and to make such observations and suggestions as truth and justice seem to demand.

Before entering into a discussion of the subject, we had better be clear about what is meant by the expression "Industrial Reconstruction." The phrase came into common use during the war, and was intended to imply, undoubtedly, a readjustment of industrial conditions in the interests of the workers, an improvement in the status of labour, a condition wherein the worker should enjoy a larger proportion of the fruit of his efforts and be granted a more effective voice in determining the conditions under which he worked. I am afraid the inexorable facts will show now the need for an extensive enlargement of the idea.

There are circumstances in the lives of men and nations which cause resolutions to be taken and good intentions for the future to be affirmed. Such an instance we are now discussing. The country was at war and in serious danger. Our national life depended not only on the strength and steadfastness of our armed forces, but on the goodwill and energy of those at home who supplied our fighting men with the material resources without which they would have been impotent.

But during this period Labour was nervous, restless, questioning. The war was won on the battle fronts in other lands, but there was more than one occasion when it might easily have been lost in the workshops at home. And so it became realised as never before that the people, above all others, whose voice must be listened to in the country, were those who could work for it and fight for it; and out of this knowledge grew a desire, which I think was sincere, to make more happy and dignified the conditions under which the bulk of the nation lived and laboured.

Not only so, but our politicians, acting after the manner of their kind, created the firm impression that, having won the war, "all other things would be added unto us." Whether actuated by generous impulse or by a desire to stiffen the morale of the people for war—who can say which?—they led the ordinary man to believe that peace would bring in its train the social and industrial ideal for which the workers longed. Our Robert Smillies would lie down with our Dukes of Northumberland, and benignant Heaven would smile upon a land at last fit for our heroes and engineers to live in. The tragedy of it all is that the promissory notes are now due and have to be presented to a well-nigh bankrupt State.

Now it seems clear that industrial reconstruction could not have been used as an alluring promise, or that the idea could not have become more or less impressed upon the national mind as a need essential, unless there existed some more or less sound basis for the belief. And there is no evidence to indicate that a need which was apparent during the war is less urgent now.

It is our part, therefore, to examine the evidence, and not only to consider the issue from the sectional point of view, which must always be dangerously incomplete, but in relation to the position, needs, and aspirations of the community as a whole. There is, in point of fact, little hope of any effective advance towards beneficial reconstruction unless we can sink the purely personal interest and bring ourselves to view the problem from the standpoint of national duty, and as a great measure of industrial, and, consequently, social advancement, undertaken by general consent and goodwill in the interests of the whole community, and not in the interests of particular sections, however important those sections may be.

Further, the problem must be viewed not only from the technician's standpoint, nor only from the economic standpoint. It is a great human problem into which enter the feelings, ambitions, passions, the whole pulsing life of the mass of our people. It is a piece of the great pageant of the history of the human race, a piece of the film on which those who follow us will view our struggles, in our day. It is too big for dogmatism. It is too big to be determined by an individual or controlled by any particular group of men, whether labelled and representative of Labour or Capital.

Let us examine the position first of all from the point of view of the Labour propagandist, who concerns himself with seeking to obtain for the workers the best terms of employment and remuneration possible; the position of the special pleader and the facts on which his argument is based.

It is true that wealth is produced by labour applied to capital; and it is argued that the wealth so produced is unfairly distributed between those who represent the two factors. It would be idle to deny that the bulk of the workers earn a wage which enables them to maintain a very ordinary standard of comfort, and that there is little margin between provision and want. It is common knowledge that if the average working-class household strikes a period of illness or unemployment, there ensues a time of acute anxiety and probably of actual physical suffering.

We all know there are everywhere conditions in our social life where deserving men, women and children exist in circumstances of poverty and distress that simply cannot be told, in the most dispassionate language, without disturbing the conscience of every decent-minded citizen. The story of the greatness of the British race would, after all, make but poor reading if it had as a prologue the dismal tale of suffering that might have been avoided.

On the other hand it would be idle to deny that there is a great deal of wealth in the country squandered in wanton, immoral extravagances, and very often by those who perform no useful function in society. In the circumstances it is not surprising that the worker demands, and still more insistently demands, an improvement in the conditions of his life. There is no man so single-minded as he who pursues a grievance, and consequently we must not be surprised even if he sometimes forgets that before wealth can be enjoyed it must first be produced. But don't let us deceive ourselves. Reconstruction is not re-division, although it may involve it, and to get a balanced view of the case we have to extend our inquiry to other factors. The employer, who, after all, is very much in a position of being the worker's banker, can only issue funds and remain solvent, so long as there is on the other side of the account a balance due for work performed.

I do not want to-night to deal with sociological theories and speculations. I take it as a fact that for the time being in the great majority of our industries, the combined efforts of Capital and Labour are necessary to produce those things by which we are enabled to live. By Capital, I mean, of course, in this use of the term, those private interests who employ labour, and I cannot find any evidence that this assumption is seriously challenged by the trades unionists themselves. After our experience of the Government's incursion into mining and railway control, I do not think the most reckless theorist would hold that the time is yet ripe for a similar experiment in the more highly complicated, technical and competitive branches of general industry. The National Federation of Trades Unions too, apparently felt there was something to be said for the present system, as affecting those branches of industry which have to live on their merits, when they recently declined the offer of a Government shipyard, on most favourable terms. Probably the best reply to Labour's destructive criticism of our present system of production, is to point out that there is no constructive attempt by Labour in any direction to assume the responsibility of replacing it.

Now it is desirable to remember that we are not a nation who can be supported upon the foodstuffs we ourselves produce. We have become a great manufacturing people because the necessity has been thrust upon us of making those commodities which others are willing to accept in exchange for the food which they can grow. And so it is that from South America, from India, China, Egypt, the Colonies and the four corners of the globe, we import those things which are necessary for our existence or desirable for our comfort, and pay for them by the agricultural machinery, manufactured cotton, steel, railways, and the hundred and one other things which we are able to give in exchange. And it has to be clearly understood that we cannot dictate to these markets our own terms. That is to say, we seek to exchange in competition with other manufacturing peoples who are similarly situated, and it therefore happens that if we place too high a value on our products, those with whom we seek to do business will refuse to trade, or, if they do, they will place upon their product a value equally high to that which we seek to impose. So that to put the matter in the plainest terms we cannot expect to send to the Argentine high-priced ploughing tractors and obtain cheap wheat in return. The cost of production in this country has a direct, definite and inevitable effect upon the quantity and cost of the foodstuffs available for our people.

We must appreciate this because it is a fundamental consideration in any scheme of reconstruction, inasmuch as reconstruction in these circumstances cannot be simply a process of distributing advantages, as so many people think; it implies also a stern necessity to produce economically, and in the utmost quantity. The only way to reach that position in which Labour's material hopes can be realised, is through hard work and efficiency in the first instance and just distribution in the second. It is doubtful whether in the lifetime of any now engaged in industry the economic outlook has been so uncertain, and so many and varied factors have combined at any one time to hamper and restrict our industrial activities.

The great market of Russia is denied us. The Balkans and Central Europe are in chaos. The Scandinavian countries are spending every penny they can in Germany because the collapse of the German exchange enables them to receive much better value than they could get if they were buying from us and paying in pounds sterling. The feeling of a large section of the people of Egypt is definitely hostile to Britain. There is a famine in Germany for raw cotton, and the result is a new reciprocity between Germany and Egypt which is leaving us in the cold. South America has almost entirely gone over to the United States, and South Africa is following suit. From all parts of the world we get the same story, that it is impossible to do business with Britain because prices are too high or other conditions are unfavourable. I do not want to labour the point. I want to show only, that they are doing reconstruction a great disservice who speak as if the only problem to be solved was the problem of how best to distribute profits. It is a much bigger problem than that, because it can be clearly shown that if we lose our grip, if we develop a slackness, the question of profits will solve itself, in a fashion little to our advantage or liking. No! I believe that St. Paul's injunction is the only sound basis of a good society, "If a man work not, neither shall he eat," and the implication is also true, that, in a figurative sense, the more man works the more shall he have to eat.

Now if we live by that which we produce, the merits and efficiency of our methods must be all-important. What are the facts? The forces of production are

* Paper read before the Association of Engineers-in-Charge, Wednesday, December 10, 1919. Mr. H. S. Hele-Shaw, D.Sc., LL.D., F.R.S., in the chair.

Capital and Labour. They are engaged jointly, and there can be no possible question that according to the harmony, co-operation and strenuousness with which they pursue their purpose, so will their success be. But instead of harmony we find a discord that could scarcely be more complete, instead of co-operation we find an evident determination to safeguard the personal interest. Instead of strenuousness we find a definite, although I will not say universal tendency to minimise the importance of effort, even when effort entails no unreasonable physical strain. Reconstruction, naturally, must aim at overcoming the absurdity of this position. There is a great temptation to discuss the possible machinery, but I have only time to generalise, and if we can agree on the general principles the machinery will come.

Firstly, then, we must have harmony, and that harmony should begin with the trades unions themselves. I heard Mr. John Hodge tell the House of Commons recently that owing to the success of the scheme of conciliation in the steel trade there had not been a strike by the members of his union for seventeen years. But in Scotland, about a month ago, 20,000 steel makers were out of work because 400 bricklayers engaged on the plant had struck. Labour is completely inter-dependent. Fifty thousand moulders on strike have seriously interrupted the employment of several hundreds of thousands of other classes of workers. The miners, to advance their own claims, have not hesitated on occasion to stop the country, and the railwaymen have the same power and are learning to use it. Disputes between unions on the demarcation of work are everyday occurrences, and it is not unknown for one union to strike against another.

If the many sections of the workers are to pursue each their own case, and cause frequent stoppages and dislocation, it really means that industry will always be in a state of more or less partial paralysis, and no system of reconstruction can be complete which does not provide for unity of interest amongst the men themselves.

When we come to the question of co-operation between employer and men, we are on even more difficult ground. The need is equally great, but the obstacles are more severe. We have to face suspicion and distrust, and it may be the remembrances of past wrongs. We have to break down the idea of opposed interests; we have to formulate a completely new Charter of Rights and establish a new conception of duties. A Labour friend of mine told me the old story that a lamb once lay down with a lion, and the next thing the lamb knew was that it was inside the lion. My answer was that as things were at present constituted it was really difficult to know which was the lion and which the lamb.

I do not discuss the circumstances or conditions which have created the present state of mind of the workers. There is much in their attitude which can be understood, even if deplored. They have inherited a tradition, confirmed by their own experience, that what they want they must fight for, and when a body of men trained in such a school become strong enough to enforce their will it is dangerously easy for them to drift into the position of saying: "What I want I take." I believe that is the unconscious attitude. The employer and the worker, the one attacking, the other defending, have drifted into opposite camps with a deep gulf between, and what the men of goodwill on both sides have now to do is to find a means of bridging that chasm and bringing the two parties together for their mutual good and the prosperity of the country.

The workers are out to get as much as they can—which is legitimate. Many of them do not feel that they have any responsibility to contribute to industry more effort than they are absolutely forced to give—which is foolish. They believe that the employers' interest is directly opposed to their own, and they pursue a course of indifference to all economic necessity which, if continued long enough, would bury both the employer and themselves in the ruins of our industrial fabric.

But I believe implicitly that this spirit of antagonism can be broken down. The necessities of the case demand it, and sooner or later both sides are bound to see the obvious. The employers will have to cultivate a much more liberal outlook than they have hitherto known. They must demonstrate beyond all doubt that they desire to give the workers a square deal. It is their duty not only as employers but as citizens to have a sympathetic regard for the very reasonable and human aspirations of the workers for an improvement in their social and industrial status. By so doing, they will contribute greatly to establishing an essential confidence, given which there is no reason why co-operation between the two should be impossible. One of the results of reconstruction would be the determination of the terms on which co-operation would be most effective.

The first condition the workers make is that the profits of industry should be equitably distributed amongst those who help to earn them, and it is doubtful if many would be found to disagree with the rightfulness of such a claim. But on the question of profits there is a good deal of loose thinking and misconception. One hears sometimes of cases where the price of a commodity has enormously increased to the consumer, where the manufacturer makes immense profits and pays bonus shares to his stockholders. Such instances are not the rule, and obtain usually in monopolised or highly specialised industries. I know of one firm of engineers whose annual wage bill is 1,000,000*l.*, who distribute in profits to their shareholders 80,000*l.*, so that if the whole of the profits were paid to the workers, it would only mean an increase of about 5*s.* per week, which increase, as a matter of fact, the distributors and retailers would promptly proceed to confiscate. This is the average position in the manufacturing side of industry, and we shall never solve the question of profit distribution until we widen our outlook and provide safeguards in other directions, to which I shall refer a little later on. There is, as you know, at present in operation a statutory limitation of the profits which may be paid away in full, and a substantial tax levied on the remainder. There is a good deal to be said for such an arrangement, and any process of reconstruction will probably make taxation on such a basis permanent.

The claim of next importance made by the workers is that they shall possess a voice in the control of that branch of industry in which they are engaged, and have a voice in the government of the particular factory in which they are employed. I cannot find anything very revolutionary or frightening in such a proposal. There is no question that they have in effect a very powerful voice now. Most employers, I think, would hesitate before trying to impose upon their workpeople conditions which were generally unacceptable, and the only departure I can find, is that we are asked to recognise frankly a position which in fact exists. But may I suggest to you that this recognition would not in any real degree improve relations or results, unless accompanied by another condition, and one too frequently ignored. The worker is the servant of his employer, but he seeks to become a partner. Now men don't enter into partnership for the purpose of exploiting their individual ends. Their prosperity can only come through the prosperity of the business, and I am convinced that if the workers could more frequently demonstrate a willingness to approach the question from the point of view of giving as well as receiving, full co-operation would soon come and be of the most tremendous advantage.

The employer is not a fool. To put the matter on the lowest terms, he knows that co-operation would pay him better than antagonism, and if he saw a disposition on the part of his men to intervene in the management for joint advantage, I believe he would readily provide the opportunity.

But apart from all this may I remind you that the Whitley Commission made certain recommendations with regard to the formation of works and Industrial Councils, which gave labour a definite standing and a definite voice. A great many of the most important trades unions have regarded these proposals with grave suspicion and mistrust. They have approached the subject as the small boy approaches the bulldog when he doesn't know whether is going to bite him or lick his hand. In fact, the most strenuous propagandists, the no-compromise, over-the-top, direct actionists, who are loudest in their demand for recognition, are frankly hostile to accepting this recognition offered. There may be reasons! The men who blew a trumpet and brought down the walls of Jericho had a much softer job than those who had to build them up.

Now let us be reasonable and practical about the matter. If the workers seek to get control by destroying the control of the employer, there is before us a period, not of reconstruction, but of destruction. If they seek control in co-operation with the employer, I see every reason to believe that the ambition will be realised. A better understanding can be effected, an *esprit* can be developed, that will have an incalculable effect for good in our industrial and national life.

But industry does not end with the production of a commodity. It has to be carried, distributed, retailed, and any proposals of reconstruction must obviously embrace these functions. Indeed, I am convinced that this aspect of the question is the most important we have to face. I indicated that our outlook on the profit question was too narrow; what actually happens? Have you seen two dogs fighting for a bone while a third sneaked in and got it? That is what happens!

We should all agree that while the amount of a man's income is important, the value which he receives for that income when he comes to spend it, is more important still. I venture to say that if the workers and their employers had directed a fraction of the time, energy, and ingenuity, they have displayed in watching and fighting one another, to a study of factors governing the distribution of commodities, the prosperity of the workers, their state of mind, the industrial atmosphere, would be absolutely different to what it is to-day.

Let me take one or two of the simplest cases I can think of within my own knowledge, as an illustration of how the system works.

A Yorkshire woollen merchant bought 100,000 pairs of socks for 7¼*d.* per pair, expecting to sell them for 9½*d.* per pair and make a reasonable profit. The market however, jumped, and those socks were eventually sold at 1*s.* 11½*d.* per pair, so that the consumer paid certainly three times the amount the article cost to produce. A man I know produces ladies' blouses. These blouses are retailed usually at 100 per cent. increase on the price which the manufacturer gets. A Scotch hosiery manufacturer was recently in Dublin. His legs were somewhat cold, and he thought he would buy a pair of pants. He went into a shop, asked for the article he required, and some samples were shown. He picked up one pair and said: "Yes, these are very nice goods, how much are they?" He was told 35*s.* "What!" he said, "35*s.*! Do you know that I made these, and what do you think I got for them? 15*s.* 6*d.*"

That sewing machine in your home cost more to sell than it did to manufacture. Of the sum you recently paid for that motor car, 25 per cent. went in selling charges. Now I take these cases because they are very simple, and because to an engineer they are probably the least compromising. But they nevertheless illustrate clearly the conditions under which our commercial life is carried on.

The distributor and retailer have a place and a function, but the point I am making is that in a very great many instances the cost of carrying out this function is too expensive to society. The plain truth of the matter is that for a generation employers and their workpeople have been so desperately concentrated on studying the movements and tactics, each of the other, that they have lost sight of many agencies which have been clinging leech-like to the limbs of both.

An essential part of any scheme of reconstruction must be to ensure that the producers and consumers are brought closer together, and that a far less proportion of the wealth of the country goes to those sections of society who act merely as agents of transfer, and contribute no really useful productive work to the community.

The position, then, broadly stated, resolves itself into this. If the employers and workers fight each other, they will slowly but effectively strangle themselves and the community. That is exactly what they are now doing, and some measure of industrial reconstruction is imperative.

Reconstruction to be effective can only be made on the basis of a friendly partnership, each partner contributing his enthusiastic support to the undertaking, and agreeing equitably to distribute the proceeds; and, further, to be complete it must provide for the elimination of many elements in our industrial system which levy a heavy toll on the wealth produced and perform no really useful service in return.

There is nothing new in these suggestions. They are commonplace to those who have been interested in the problem; but the fact remains that we can make no real progress until the spirit of them has been accepted. All the machinery we can devise of arbitration, conciliation, control will fall to pieces on the first occasion of stress, unless the employers and workpeople do something to clear the industrial atmosphere of its poisonous currents, by the cultivation of good faith and goodwill. It is a spiritual question much more than a material. The future of the nation depends on the possibility of finding men on both sides, wise, tolerant and just, strong enough to crush reaction on the one hand, and blatant, selfish, destructive tyranny on the other. And I for one believe it can be done.

We passed through the tragedy and devastation of a world war. There were times in that period of terrible stress when, as individuals, we suffered the greatest loss we could be called upon to sustain. As a people we were more than once in sight of the greatest calamity that can befall a nation. Only the historian of the future can pay adequate tribute to the strength, fortitude, unity and sacrifice of the British race during that time of danger, and measure the debt that the world of the future owes to the disinterested efforts then put forth. But those achievements which, in the pages of history, will thrill generations to come, have a message for those of us who hold them still in sight. They tell us that a people who struggle and suffer, but who fight on and win, who are branded and scarred and beaten to the ropes, only to recover and destroy their enemy, have a mind too strong, a spirit too great, and a destiny too certain, for any doubt to exist about the possibility of finding a solution for their domestic difficulties. This is the spirit in which the Labour problem should be approached, and given this spirit there is nothing we may fear.

DIRECTION AND POSITION FINDING.*

By Captain H. J. ROUND.

(*Concluded from page* 112.)

FURTHER IMPROVEMENTS.

In an earlier part of the paper I have indicated that one of our difficulties was rapid searching over long ranges of wave-length. The first real solution of the problem on Bellini-Tosi was indicated by G. M. Wright in 1915, who suggested that the aerial tuning condensers should be short-circuited and a closer coupling made between the search coil and the aerial inductances. A first trial of this method resulted in serious errors and weak signals. I revived the method a few months later for continuous wave work. It was well known that weak continuous waves could be amplified by a low-frequency amplifier, whereas a high-frequency amplifier was necessary for spark signals on account of the fact that a rectifier without heterodyne increases in efficiency with increase of signals, whereas a rectifier with a heterodyne has practically a constant efficiency. Consequently, with continuous waves it was merely necessary first to rectify and heterodyne, and then low-frequency amplify to the extent required.

With spark signals at that time, aperiodic cascade amplifiation was undeveloped, and the cascade tuned amplifiers we had were impossible for rapid searching on many wave-lengths. In view of this I recognised the possibilities, for continuous wave, of Wright's form of aerial, and it enabled me to obtain a circuit with only one condenser to tune—a particularly necessary condition with continuous waves as the tuning is so fine.

A previous trial by Wright had indicated that independent heterodyne circuits were troublesome on direction finders because of the unequal action of the heterodyne on the two aerials. Also the addition of the extra heterodyne condenser reduced the simplicity of the one condenser circuit, therefore self-heterodyne circuits were adopted. In the first trial of this system at a coast station I at once noticed again very serious errors and bad minima. This turned out to be the "Vertical" in a greatly exaggerated form. The reason for this exaggeration is that, as the frame is now untuned, the component representing the directional receptive power of the aerial has been considerably reduced, and the component representing "Vertical" reception is now of a sufficient relative magnitude to affect materially the observed direction. A simple

* Paper read before the Institution of Electrical Engineers, January 14, 1920.

solution was obtained which was suitable for all waves above 1,000 m., and which consisted in earthing the mid-points of the two direction-finder coils.

The minima in the daytime were now very sharp and the directions accurate. With only slight modifications of apparatus this remained our standard continuous wave apparatus during the remainder of the war. This was also the basis of the "aperiodic" spark direction finder when the cascade amplifiers were produced. (Fig. 24.)

Hard Valves.—All through the work up to 1917 we had used various forms of soft tubes. I had received early in the war information and tubes of a harder character from America, but we could not use these as we had erected such a high standard of sensitiveness with the soft valve that in transferring to hard valves we should have lost a lot of useful results. We did, however, in certain cases, succeed in obtaining fair sensitiveness with hard tubes by the process of stepping up potentials on the grids to the maximum possible, and by paralleling several tubes.

Cascade Amplifiers.—However, Lieutenant W. J. Picken succeeded in June, 1916, in getting five high-frequency magnifications on 200 m. by tuned circuits with much harder stable tubes, and he obtained such extraordinary magnification that we started to find out how to handle these circuits.

One form of circuit, suggested by Russell Clarke's multiple-tuning circuits, consisted of a number of circuits loosely coupled together with all the tuning variometers moving together. The initial trouble in tuning, and the final narrow range of wave-length owing to reaction oscillating troubles, made the gear only possible for very special work.

In an attempt to get rid of the reaction trouble, we gradually recognised that the real solution of the problem would be in trying not to get too much magnification per valve, and at this point I inserted resistances in all my circuits to damp the oscillations out. The French modification of the audion was by that time in general use, and the French had already constructed resistance cascade amplifiers for long waves.

Any attempt on my part to construct resistance amplifiers failed, and the reason soon became obvious. For waves under 1,000 m.—and we had no living interest in longer waves—the capacity of the valves themselves and of the connections to them formed an impedance which was lower than the lowest resistance that gave cascade magnification.

Colonel Blandy kindly lent me a Latour transformer amplifier, and a careful study of this indicated that my previous cascade amplifier, with resistance to stop reaction, was the right thing, but it had not been taken far enough.

Sufficient ideas were now in hand to start the design of a cascade amplifier for short waves.

Latour's ideas had produced a moderately aperiodic amplifier, but the magnification was still short of the best soft-valve arrangements, and the wave-length was still too long, especially for Army purposes.

The Latour amplifier with iron transformer depended for its quasi aperiodic curves in the large ratio of L/C given by iron-core windings, and also on the damping applied by this iron, as well as that applied by the valves. The first important range of wave-length attacked was for an Army amplifier with a range of from 250 m. to 1,000 m.

We soon recognised that to obtain a great ratio of L/C the iron was hardly necessary, as coils could be wound with fine wire of considerably smaller self-capacity than the valves and leads.

A three-valve cascade amplifier, built with fine wire coils of one layer, gave a result as good as the Latour amplifier, but the addition of more valves at once caused serious oscillations, and a grid potentiometer became necessary to prevent oscillations, *i.e.*, to give grid damping to the circuits. Valves were then constructed with more open grids and with all capacities cut down to a minimum, and with these valves, four-valve, high-frequency magnifiers were constructed, with the new advantage that the plate potential, owing to the more open mesh in the valves, was reduced to 24 volts. Still the aperiodicity was not yet sufficient, and the magnification required was present over a range of only 200 m.

The copper inter-valve windings were now replaced by resistance wire wound to exactly the same dimensions, which wire for all ordinary work consisted of No. 48 "Eureka." The set now allowed of the use of six valves plus a rectifier, with practically no adjustments and a flatness of tuning which was almost all, if not quite all, that could be desired. Obviously still better results would be obtained by still greater resistance in the coils and more valves, but seven valves were considered to be quite enough for maintenance of valves and valve current.

The damping applied by the resistance was now of the same order as that applied by the valves themselves, and any variations in valve constants were balanced, so that one no longer had the condition given by copper coils, which was that one valve would make the set oscillate and another would not.

A further set was made up from 400 m. to 2,000 m. by using longer coils, and the much more difficult range of 100 m. to 300 m. required by the Army was then attacked.

The coils required were now so short and the valve capacities comparatively so much more, that the damping provided by the No. 48 "Eureka" wire was insufficient to give, without the sets oscillating, the required magnification and range of wave-length.

At this point Messrs. Edison and Swan offered to draw nickel-chrome wire down to 1 mil in thickness for me. The resistance of this wire for the same length is about 3½ times that of No. 48 "Eureka." This was very satisfactory, and a very good degree of flatness was obtained with the seven valves over the range of wave-length required.

The magnification is not so good as the longer wave sets, but it was a very great improvement on anything hitherto produced.

Still shorter wave sets have been produced with this wire. Of course, the shorter the wave-length the narrower the range which can be obtained, but cascade sets with a range of from 30 m. to 50 m. can easily be produced if such wave-lengths are ever required.

Using this wire with coils wound of the same length as the first amplifier mentioned, a set of 11 valves has been made of approximately equal sensitiveness from 250 m. to 10,000 m.; the higher values being obtained by using the resistance potential drop across the coils, and the shorter wave magnification, as before, being due to the neutralisation of the capacity effects by the inductance.

Both the initial and maintenance expense of such a set rather prohibits its use at present, and actually such a range of wave-lengths is seldom required.

Many sets were made up for special work, a standard set of 11 valves being used for short waves in which the damping of the valve circuit was less than the extreme values used above, because only narrow ranges of wave-length were required. This set had a voltage amplification at 200 m. of 2,000, and when more magnification was required, two sets could be loosely coupled together without running into oscillation troubles.

"Aperiodic" Aerial Spark Sets.—"Aperiodic" amplification was now all that could be desired, a rather heavy consumption of valves and valve current being the only disadvantages. I may mention that at one group of naval stations a pair of 7-h.p. charging engines were found necessary, and 130 valves were running continuously.

Almost at once, quick-search one-condenser aperiodic direction finders came into use for spark waves. I must admit, however, that an operator is absolutely insatiable with regard to signal intensity. As the "aperiodic" aerials gave slightly weaker signals than the tuned ones, although these signals were far stronger than those given by the old gear, one usually found the operator with the tuning condensers inserted in the aerial in order to get the last fraction of signal strength.

With the introduction of the "aperiodic" direction finder, we found that direct reception on any of the coils in the receiver was introducing slight errors. In the case of the search coil of the radiogoniometer, this can be avoided by placing the radiogoniometer in a correct position on the table. In the case of all other coils, it is avoided by metal shielding.

Fig. 25 shows the arrangement, finally arrived at, of the spark-wave direction finder. The metal shield inserted between the windings of the transformer is an effective method of avoiding "vertical," except on waves under 400 m., when in addition it is necessary to earth the centre of the aerial. The diagram shows nine valves; six of these are for high-frequency magnification, the seventh for rectification, and the last two for low-frequency magnification.

Direction finders for 200 m., constructed with 11 or 22 valves in cascade, enabled us to watch with ease certain "buzzer" intercommunicating sets, and this with no more error than on the longer wave sets. In these 22-valve sets, 11 valves were connected with quasi-aperiodic transformers, a loose tuned coupling was then inserted, and another 11-valve set added. In addition, usually one or two low-frequency amplifiers were added at the end. I measured the total high-frequency magnification at about 500,000.

Fig. 24.

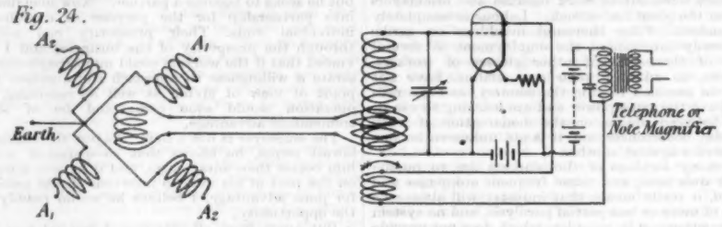


Fig. 25.

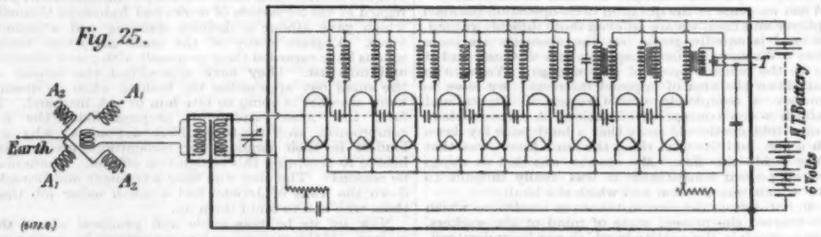


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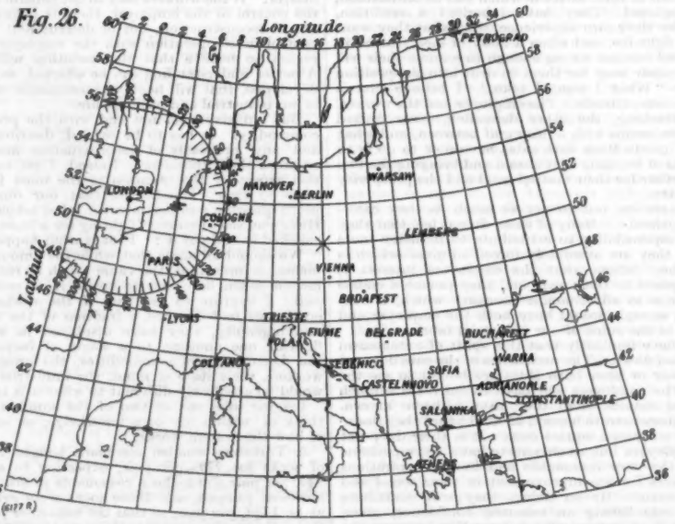
Fig. 26.



(5177.)

I stated that the continuous-wave direction finder was very little changed after the first set; actually, however, high-frequency amplifiers were used for two reasons. First, a self-heterodyning cascade amplifier is, for some not obvious reason, much less subject to microphonic noises than is a single valve; and secondly, the amount of continuous-wave current produced in the aerial by the self-heterodyne is very considerably less in the case of a cascade amplifier than in the case of a single valve. This enables stations quite close to one another to search over overlapping ranges of wave-length without howling at one another.

Operators.—A curious fact in connection with the introduction of the fool-proof direction finder was that the operators were rather unhappy with them. In the early days, when potentiometers, resistances, and a multitude of condensers had to be adjusted, time passed easily on watch, and an element of competition entered into the game as to who could get the best valve adjustments. Now all that vanished and they were reduced to mere operators again.

I cannot say too much for the high standard of all

the operators with whom I came into contact. The keenness of the men really made a doubtful art successful. I have sat through a busy time with Zeppelins, and watched the great speed at which the men took readings, one single swing being sufficient. With my own ear trained to judge signal strength and equality I could never criticize their readings.

Some of the men showed very great interest in the growth of the subject technically, and many valuable suggestions came from them. Some of them became excellent amateur mechanics, and two in particular made for me all the original cascade amplifiers. Others concentrated on intelligence work and gave many valuable suggestions as to what further work we could do.

I have seen it stated that of those engaged in technical work in the war there are many who would like to meet their opposite numbers in the enemy camp, in order to compare notes. One general feeling amongst the Naval Intelligence operators, I know, is to meet the one operator who controlled the German Zeppelins and warships. They always imagined it was one particular man who was a super-operator. On several occasions with 9 or 10 Zeppelins in a raid, all frantically trying to communicate with home for bearings or otherwise, wireless occasionally got into a horrible tangle. At that moment the superman would arrive, take control, and in a twinkling all would be peace and order.

Maps.—In certain side lines direction-finding required investigation work, more particularly in map production. In the first few months we used Mercator charts with great circles every 5 deg. drawn through each of our stations. These were very troublesome to use. A great improvement, due to Lieutenant-Colonel Simpson, Captain Edmunds, Mr. J. St. V. Pletts, and the Royal Geographical Society, came when map projections commonly called "gnomonic projection" were produced specially for our work. In these projections, the great circles are straight lines and directions are correct for one point and very nearly correct for points over a large area.

A simple way to consider this type of map is to imagine the shadow thrown on a tangent plane to the globe by a candle at the centre of the globe. It can then be seen that the shadows of all great circles are straight lines and that all angles at the tangent point are true. With the aid of these maps and various ingenious strings, springs and weights, headquarters could keep up rapid and continuous plotting of the tremendous mass of direction-finder readings coming in during busy times from the many stations.

If one wanted to work from a station very much away from the tangent point, it was sufficient to have round the map a protractor calculated for that point. A gnomonic projection of Europe is shown in Fig. 26.

Atmospherics.—An interesting side line on direction-finding work was its bearing on X-stopping. I can give, however, very little data on this subject. During daytime, on one or two occasions, the positions of thunderstorms were approximately determined and checked, but this was not often possible. At night time particularly in spring and autumn, X's exhibited very frequently—in fact, most of the time in England—a sharp direction which varied a little round the position of 165 deg. E. of N.

The minimum is often extremely sharp, exactly like a well-defined station. It was suggested—I believe by Mr. Cave of the Meteorological Office, Farnborough—that this direction was curiously near the magnetic meridian and perhaps it may be possible to determine if freak signals, and consequently X's, have more tendency to be reflected along the earth's magnetic field, by the Heaviside layer. Unfortunately, observations in other parts of the world are not yet collected.

We were able to use this direction of X's for intercepting purposes, as it was fortunately almost at right angles to the direction of the Heligoland Bight. Signals on a vertical aerial, absolutely inaudible owing to X's, were clear without X's in a frame roughly placed at 75 deg. E. of N.

Frame Aerials.—One is often asked about reception on a frame aerial, what circuits should be used, and what is the number of turns that should be used for any wave-length. If the frame required is large, and if it is proposed to use a coupled circuit to the detector, a one-turn frame is as good as anything else, provided one has enough capacity in the condenser to tune it up to the necessary wave-length, and that one takes care of the resistance losses of the wire used and the losses in the condenser.

If the frame to be used is small, very often the leading-in wires have an inductance of the order of the frame. This results not only in a reduction of signals, but in a diagram of reception which does not agree with the frame diagram, if the leading-in wires enclose an area which can receive. If direct reception is required on a frame, and this, as far as sensitiveness goes is the most efficient method, then with all modern amplifiers with a non-conducting grid circuit the frame should have the maximum number of turns and the smallest condenser which the receiver will take. This limit is usually defined by the amplifier oscillating beyond control.

The previously mentioned correction for "vertical" should then be applied. In loose-coupled circuits most of the "vertical" trouble can be avoided by allowing the aerial only to induce magnetically on a few turns inserted in the transformer secondary between the filament battery and the main transformer secondary. This is indicated in the diagram (Fig. 27), where only one valve in the amplifier is shown.

Direction Finding on Ships and Aeroplanes.—Quite early in the war several ships of His Majesty's Navy were fitted with direction-finding apparatus, but no good chance to investigate errors on board ship really occurred till early 1918. Even before the war, it was well recognised that there was a tendency to give errors which crowded the readings towards a fore and aft direction. Commander Dorling of H.M.S. Warspite succeeded in obtaining a very large number of readings on the Warspite and produced an error curve. I append this curve (Fig. 28). The crowding of all the readings towards the 0 deg. and 180 deg. directions, i.e., fore and

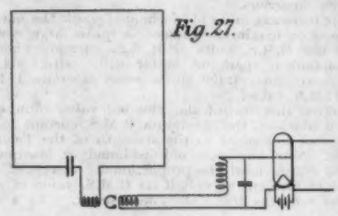


Fig. 27.

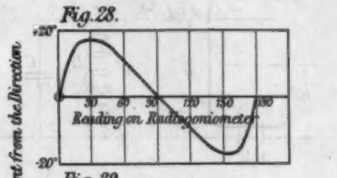


Fig. 28.

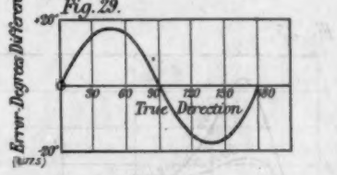


Fig. 29.

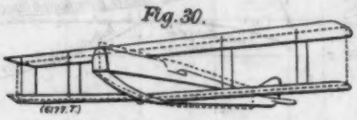


Fig. 30.

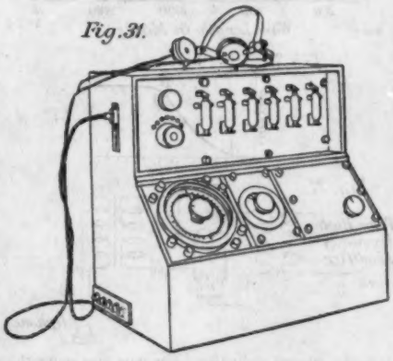


Fig. 31.

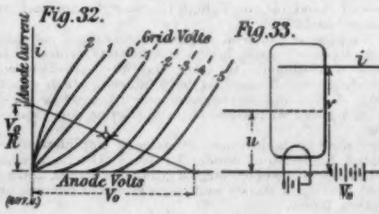


Fig. 32.

Fig. 33.

aft, was very troublesome for taking readings, and we decided to attempt a modification of the Bellini-Tosi system to correct these errors, which amounted in other cases to as much as 30 deg.

Only since the armistice have I had an opportunity of trying out direction finders on aeroplanes. The four-engine Handley-Page, which went to Newfoundland, was fitted with an extemporised Bellini-Tosi, using an aerial system exactly as on board ship. One aerial was lengthwise round the wings, and the other lengthwise round the fuselage (Fig. 30). A correction which was made on the ground was found to hold good when the plane was in the air. An eight-valve long-wave amplifier set gave very satisfactory signals. Magneto noises which were extremely bad owing to the large number of magnetos, were overcome by shielding the magneto leads and, what was more important still, by shielding the complete receiver system with the exception of the aerials. When the engines were running all out, almost complete silence could be obtained. This set was used effectively in the flight from St. John's to the United States, during which flight directions were taken on Clifden. Similar machines have been fitted since, and the same satisfactory results obtained.

I believe the chief use made of the corrected Bellini-Tosi system for ships was in convoy work, but previously the Tenth Cruiser Squadron and other ships had used it during cruising.

All this later work on ships was done with Wright's inductive loop aerial or "aperiodic" aerial, and Wright has during the last year developed an extremely small and practical ship direction finder for use with this type of corrected frame (Fig. 31). It is intended to apply the necessary corrections on every ship, with periodical examinations of the corrections when the ship is in port, exactly as a ship's compass is treated.

One advantage a warship has over most merchantmen is that there is fitted a gyro compass with reposter compasses, one of which can be near the direction-finder. If no gyro compass is fitted, the exact direction of the ship is extremely difficult to get simultaneously with the reading taken on the radiogoniometer, especially if the ship is turning or yawing. A useful addition to a ship's direction finder would be a magnetic compass repeater.

Fig. 28, which gives approximately the original error curve of the Warspite, were obtained on a Bellini-Tosi system consisting of two frames each placed at 45 deg. to the fore and aft line of the ship. In the first form the shape of the curve was rather puzzling, because the error was plotted against the readings. On replotting the errors against the true directions (Fig. 29), the curve became a sine curve.

CONCLUSION.

I am afraid that if I attempted to mention the names of all those who have assisted me during the last five years either directly or by advice, I should take up a large portion of this paper. However, I can never forget the valuable help and support of Colonel Blandy, R.E., of Captain Slee, R.N., of all the Wireless and intelligence men at the War Office, the Admiralty the Signal School, the Grand Fleet and Queenstown. Also to my own assistants at different times during this period, Lieutenant-Commander W. T. Ditcham, Captain Tremellen, Lieutenants G. M. Wright, W. J. Picken, J. G. Robb, G. C. Meikle, A. W. Hall and Mr. F. P. Swann.

APPENDIX I.

The action of a wave on two spaced aerials can be written down when subtracted as :—

$$\sin p\,(t - \tfrac{1}{2}\,T\cos\theta) - \sin p\,(t + \tfrac{1}{2}\,T\cos\theta)$$

where T is the time taken for a wave to travel from one aerial to another, and θ is the angle between the direction of the wave and the plane of the two aerials.

This is proportional to $\cos p\,t \sin(\tfrac{1}{2}\,p\,T\cos\theta)$

$$p\,T/2 = 2\,\pi\,n\,T/2 = \pi\,T/T_o$$

where T_o is the time taken for a wave to travel one complete wave-length.

$\sin[\pi\,(T/T_o)\cos\theta]$ is equal to $(\pi\,T/T_o)\cos\theta$, if T is small compared with T_o, so that the expression $A\cos p\,t\cos\theta$ represents for a small frame the electromotive force induced. The phase of the electromotive force is 90 deg. away from the phase of the electromotive force induced in one aerial.

With a frame, the effect of the term $\sin[(\pi T/T_o)\cos\theta]$ being different from $(\pi T/T_o)\cos\theta$ if the frame is large, makes no difference to our reading of the minimum of signals, but with the Bellini-Tosi the effect is to cause an octantal error.

Thus if θ is the true direction with regard to the phase of one of the aerials and ϕ the error, then

$$\tan(\theta + \phi) = \frac{\sin[(\pi\,T/T_o)\sin\theta]}{\sin[(\pi\,T/T_o)\cos\theta]}$$

ϕ is zero for $\theta = 0$, 45 deg., 90 deg., 135 deg., and 180 deg., rising to a maximum between each of these pairs of readings. This error is actually extremely small with valves of T/T_o up to 1/10.

APPENDIX II.

In the elementary consideration of the valve as an amplifier, it simplifies the initial considerations to neglect reaction effects. Grid current can also be neglected. If the characteristics of a three-electrode valve are drawn out (Fig. 32), plotting anode current against anode volts, a set of characteristics is obtained, each taken at constant grid volts.

If the valve is inserted into a circuit, whatever happens in the rest of the circuit the valve must obey the law given by this set of characteristics. For very small amplitude changes, this surface can be represented by the equation :—

$$i = u/r_1 + v/r_2 + K$$

where i = anode current,
u = grid volts,
v = anode volts

K may be eliminated by a suitable shift of the zero of the axes O, and the equation then becomes :

$$i = u/r_1 + v/r_2$$

Let an element of the resistance amplifier be taken (Fig. 33). Then in the anode circuit there is a battery of voltage V_o, and also a resistance R. The voltage across the resistance rod equals $(V_o - v)$, therefore :

$$i = (V_o - v)/R$$

This represents a straight line, which is shown in

Fig. 33. If again the zero position is changed to O (Fig. 33), then $i = -v/R$ is the equation of this line.

For any change of grid volts, it is now possible to read off the change of anode current and anode volts.

Instead of a graphical determination the solution may be obtained as follows :—

$$i = -\frac{v}{R}; \quad i = \frac{u}{r_1} + \frac{v}{r_2}$$

either i or v may be eliminated.

Eliminating i :

$$-\frac{v}{R} = \frac{u}{r_1} + \frac{v}{r_2}$$

$$\therefore \quad \frac{u}{r_1} + v\left(\frac{1}{r_2} + \frac{1}{R}\right) = 0$$

$$\frac{u}{r_1} = -v\left(\frac{1}{r_2} + \frac{1}{R}\right) \text{ or } \frac{u}{v} = -r_1\left(\frac{1}{r_2} + \frac{1}{R}\right)$$

This expression has its smallest value when $R = \infty$.

When $R = \infty$, v/u is usually called the voltage amplification factor of the valve and is equal to r_2/r_1.

If R becomes negative, as in the case of a dynatron, and $R = -r_2$, then v/u becomes infinitely large.

In the case when the more complex general circuit s attached to the valve (see Fig. 34), if i_1, i_2 and i_3 are the three currents flowing in L, C and R respectively, and i is the sum of these, then :

$$i = i_1 + i_2 + i_3 = \frac{u}{r_1} + \frac{v}{r_2}$$

Let $v = A \sin p t$. i is given by the solution of :

$$L\frac{d\,i}{d\,t} + R\,i = A \sin p t$$

that is

$$i_1 = -A\left[\frac{r_2 \sin p t - p L \cos p t}{r_2^2 + p^2 L^2}\right]$$

The minus sign appears for the same reason as in the simpler resistance case. A rise of volts across R is accompanied by a drop across anything else in series with it.

Also

$$i_2 = -C\frac{d\,v}{d\,t} = -C A p \cos p t$$

and

$$i_3 = -\frac{v}{R} = -\frac{A \sin p t}{R}$$

then

$$-i = -\frac{u}{r_1} - \frac{A \sin p t}{r_2}$$

$$= \frac{A \sin p t}{R} + C A p \cos p t + \frac{A r_2 \sin p t}{r_2^2 + p^2 L^2} - \frac{A p L \cos p t}{r_2^2 + p^2 L^2}$$

or

$$-\frac{u}{r_1}$$

$$= A\left[\frac{1}{R} + \frac{1}{r_2} + \frac{r_2}{r_2^2 + p^2 L^2}\right] \sin p t + A'\left[C p - \frac{p L}{r_2^2 + p^2 L^2}\right] \cos p t$$

Calling the amplitude of $u = A'$

$$A' = A r_1 \sqrt{\left[\frac{1}{R} + \frac{1}{r_2} + \frac{r_2}{r_2^2 + p^2 L^2}\right]^2 + \left[C p - \frac{p L}{r^2 + p^2 L^2}\right]^2}$$

This general formula giving A'/A will serve to indicate the amplification curves of three cases of the valve amplifier, the figures, however, not referring to any actual case.

(1) Let $L = 0$; $C = 10^{-11}$; $R = \infty$; $r_2 = 20{,}000$; $r_3 = 20{,}000$ $r_1 = 3{,}300$.

This is the case of a resistance amplifier with capacity due to valves and leads, shunting the resistance.

Curve 1 (Fig. 35) shows the variation of A'/A with wave-length.

(2) Let $L = 1/220$; $C = 10^{-11}$; $R = \infty$; $r_2 = 20{,}000$ $r_3 = 0$; $r_1 = 3{,}300$.

This is the case of an inductance with capacity and no resistance and is shown in Curve 2 (Fig. 35).

(3) Let $L = 1/220$; $C = 10^{-11}$; $R = \infty$; $r_2 = 20{,}000$; $r_3 = 20{,}000$; $r_1 = 3{,}300$.

This is the case of an inductance wound with resistance wire with capacity, and is shown in Curve 3 (Fig. 35).

Where it is required, the amplification can be kept up on the shorter wave-lengths in the manner shown by Curve 3.

The curves for several valves in cascade can be calculated by taking the new amplitudes and applying the formula again ; or merely by squaring, cubing, &c., the first curves obtained.

A fair agreement can be obtained between experiment and this simple theory, if during the experiments reaction is eliminated. In general, for spark work, it can be assumed that full reaction multiplies voltage magnification by 7 or 8, if a practical adjustment is all that is permitted.

APPENDIX III.

One of the great difficulties during the war was the jamming experienced in busy times, and the problem of jamming prevention during direction-finding work is not at all the same as jamming prevention during reception.

If, during the action of taking a swing reading, a strong station is sending, it is very difficult to obtain the necessary balance of signal strength, as the jammer, being in another direction, exhibits unequal strengths at the two swing positions.

A little was done with note-tuning by means of a valve reaction circuit tuned to the Telefunken notes.

However, in an attempt to develop one method, another was developed which turned out of great use in the allied work of interception, and it will probably be of use to describe it here.

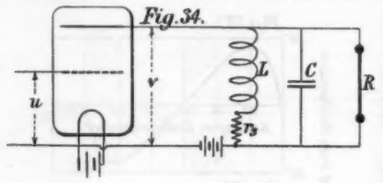
In about 1910, Mr. C. S. Franklin and the writer devised the two now well-known ways of limiting strong signals :—

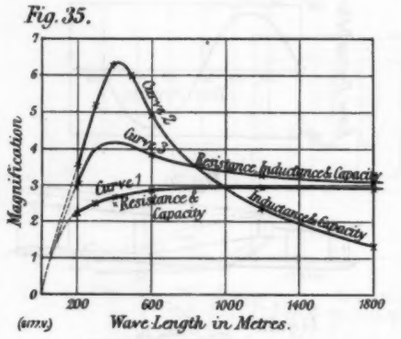
1. The Fleming valve current saturation method.
2. The Fleming valve or crystal, balance method.

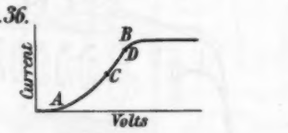
Both these methods depended on the fact that signals of equal strength do not necessarily have the same maximum voltages or currents for the same R.M.S. values of current.

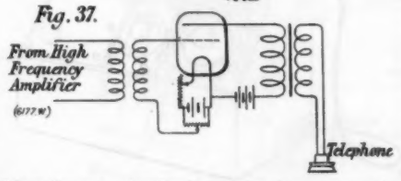
For instance, in an old-fashioned spark the maximum voltage or maximum current is quite large compared with the R.M.S. volts or R.M.S. current, whereas in a Telefunken spark or, better still, continuous waves the maximum voltage and current are only 1·4 times the R.M.S. value.

Taking the case of the Fleming valve running with a dull filament, the maximum R.M.S. current that can pass can be limited to the strength of the Telefunken spark. Now any slow old-fashioned or low-note disc spark will obviously be proportionally weakened at this value of filament current if its R.M.S. value of current is the same as this Telefunken spark. (As a matter









of fact the general reduction of signals was more than one could stand for, until high-frequency amplification was introduced).

In the case of balanced valves or crystals, a voltage-limiting scheme is used, but in this method, which with crystals was difficult to work but very good when obtained, a new effect could be produced, which effect was the elimination of strong signals from weak ones, both strong and weak signals being on the same wave-length.

After the first high-frequency cascade amplifiers were produced, Lieutenant-Commander W. T. Ditcham, who was in charge of one of the largest group of stations, undertook to develop a simple and more effective balance or saturation device.

The result was so simple to adjust, and so effective that we introduced it for all interception work, and I believe a good many ship working stations used it with great effect.

Ditcham's arrangement consisted in dulling down a valve, and instead of working at the rectifying point having a potentiometer which controlled the characteristic from end to end.

He then found that with a particular filament brilliancy at one point on the potentiometer one station would vanish, and at another point a different station would vanish.

An extremely fine potentiometer adjustment was required to get the best effects, as the zero point of two stations will be separated by as little as 1/100th of a volt charge on the potentiometer.

The success of the device depended on plenty of high-frequency magnification before rectification, as these special points on the rectifying valve were rather inefficient rectifiers.

I can perhaps explain how this effect occurs.

Suppose a weak Telefunken station is being received and on the same wave-length a strong station with preferably a lower musical or unmusical note is also being received. The valve is dulled down to a value which prevents the full value of the loud station current passing through the valve.

If we draw the characteristic of such a valve. A and B are the two maximum rectifying points. Now as the strong station voltage amplitude is at least from A to B horizontally, it can easily be seen that an approximate zero of rectification will be obtained at C, the middle of the curve, but as in nearly all valves the curvature of the rectifying point is not the same at A and B—the zero rectifying point for the weak signal will not be at C, but at some point of D, the point of inflexion on the curve. The result is that at C the strong station vanishes but the weak station is still heard.

Those who have a high-frequency amplifier of any type, preferably with inter-valve transformers wound with copper wire, and not having resistance rods and grid leaks, can try this, as almost any three or two-electrode valve shows the effect.

It is proposed to introduce a modification of this scheme, even simpler than the above, into all ship receivers for spark work. The amplifier to be provided is sufficiently sensitive, without the balance scheme, that ranges are increased very greatly over those with crystals only, and with the balance scheme the sensitiveness is about that of a crystal. In compensation, however, by the adjustment of one handle one is able to eliminate jamming.

This scheme enabled us to use note tuning much more effectively, for the signal strength was then not sufficient to set our note reaction circuit oscillating in its own period for a relatively long time, as is the case with strong signals.

We have noticed that the scheme is extremely effective on short waves for wireless telephony, for in such a case one has the limiting difference between sparks and continuous oscillations, and sparks can be almost all eliminated.

Unfortunately, I cannot say that its use is of equally great value for long-wave working, for with long waves there is not such a big difference between the maximum and R.M.S. value of currents.

The above saturation balance method was occasionally of use in direction-finding work, but its use was not at all general as the tendency is to require a curve which, if anything, exaggerates the cosine diagram.

DESTRUCTION OF IMPORTANT DUTCH BRICKYARDS.—We read in *The Board of Trade Journal* that owing to inundations of the outlying fields by the Rivers Maas and Rhine, a serious catastrophe has occurred in the Dutch brick-making industry which will be felt for years in the building trade. H.M. Commercial Secretary at The Hague states that 16 brickyards, containing 100,000,000 unbaked and 25,000,000 to 50,000,000 baked bricks have been entirely destroyed, and it is feared that the usual high water in March will complete the destruction of many others which have already been damaged considerably. The reason why there were so many unbaked bricks in store at the present time is said to be owing to the fact that lack of transport and fuel has prevented the firing of many unbaked stocks.

A NEW CONDENSER.—A description comes to us of a new condenser brought out by the Wheeler Condenser and Engineering Company, of Carteret, N.J., U.S.A. This has been designed by Mr. S. Morris Lillie with the object of preventing any trouble from condensing water leaking into and mixing with the feed. At one end of the condenser the tubes are expanded into the tube-plate in the ordinary way. At the other end the joint is made with packing, but a diaphragm plate is added a short distance away from the actual tube-plate, on the feed-water side. The tubes are a sliding fit in this diaphragm, which therefore divides the interior of the condenser between the tube plates into two, viz., one main portion occupying nearly the whole of the interior, and a smaller section adjacent to the tube-plate in which the tubes are held with ferrules and packing. At the bottom of this section is a drain leading to a small pump or vacuum trap. Any leakage of the circulating water past the ferrules and packing is drawn off from this partition by the drain below, and does not pass beyond the diaphragm into the main section of the condenser, in which therefore the condensate is uncontaminated.

STREATHAM JUNCTION COLLISION.—Colonel J. W. Pringle's report on the collision which occurred on the London, Brighton and South Coast Railway near Streatham Junction, on November 3 last, places the blame jointly on Driver May and Signalman Forster. In this accident a light engine proceeding from Eardly Carriage Sidings to Battersea overran a signal incorrectly given for New Cross. The driver reported to the signalman that he wanted Battersea and not New Cross, and the line was obtained for him and altered. The engine, however, appears to have been standing beyond the points at the time, and on being given steam continued on the wrong road, finally colliding with a Portsmouth train. The driver is blamed for letting his engine run past a signal which he knew was not the one he wanted, and for failing to recognise that he was standing on the wrong side of facing points which had to be reversed. The signalman is blamed for not making sure of the position of the engine on the road before he reversed the points. Colonel Pringle points out that in this case track-circuiting instead of treadle control, would have prevented the signalman from making such a mistake, as it would have informed him of the position of the light engine.